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ABSTRACT

Brief papers authored by staff of the Trace Research and Development Center on Communication, Control, and Computer Access for Handicapped Individuals and presented at the first through ninth annual conferences on rehabilitation engineering technology are presented. Papers have the following titles and authors: "The Data Routing Module: Accessing Computer Systems with Communication Aids" (B. Rodgers et al.); "Application of an Optical Keyboard for Job-Site Access to Standard Computer Systems" (G. Goldberg); "Two Headpointing Input Techniques--A Comparative Study" (M. Brady et al.); "Generic Keyboard Emulator Architecture for Transparent Access to Standard Software by Handicapped Individuals" (D. Kelso and J. Gunderson); "A Multipurpose Stand Alone Expanded Keyboard for the Disabled" (P. Graystone et al.); "A High-Efficiency Flexible Keyboard Input Acceleration Technique: Speedkey" (G. Vanderheiden); "Development of a Set of International Communication Aids Compatibility Standards Proposals (ICAC SIDS)" (B. Rodgers and J. Gunderson); "A Portable Computer-Based Writing, Conversation and Computer Access Aid for Severely Motor Impaired Individuals" (J. Gunderson and G. Vanderheiden); "Minibus Architecture for Increased Function and Longevity of Communication and Control Aids" (G. Vanderheiden and D. Kelso); "Use of Transparent Input and Feedback Modification to Allow Access to Standard Educational and Vocational Software" (G. Vanderheiden and D. Kelso); "The Talking Blissapple: A User Programmable Pictographic Communication/Writing Program for Severely Handicapped Individuals" (G. Vanderheiden and D. Kelso); "A Data-Based Approach to Character/Syllable/Word Sets" (M. Brady et al.); "A Standard Interconnection Format for Electronic Assistive Devices for Handicapped Individuals" (B. Rodgers et al.); "Dual and Nested Computer Approach to Vocational and Educational Computer Systems" (G. Vanderheiden and D. Kelso); "Hybrid Optical Headpointing

Technique" (G. Vanderheiden); "Design of Universal Keyboard Emulators" (B. Rodgers); "Ten-Branch Abbreviation Expansion for Greater Efficiency in Augmentative Communication Systems" (D. Kelso and G. Vanderheiden); "The Effect of Increased Sensor Area on Input Rate and Accuracy of the Express III Communication Aid" (C. Lee and G. Vanderheiden); "Alternate Access to All Standard Computers for Disabled and Non-Disabled Users" (G. Vanderheiden); "A Portable DECtalk Speech Synthesizer" (C. Lee and D. Kelso); "The Design and Testing of a Tutorial Manual That Allowed Users To Learn a Multifunction Aid System without Expert Support" (B. Rodgers); "One Finger Operation of the IBM Family of Personal Computers" (C. Lee et al.); and "Application of Multiple Wordstudy Analysis in the Development of Vocabularies for Augmentative Communication Systems" (C. Cress and G. Vanderheiden). (DB)

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TRACE AUTHORED PAPERS FROM THE FIRST THROUGH SEVENTH ANNUAL CONFERENCES ON REHABILITATION ENGINEERING TECHNOLOGY - 1977-1984

Brady, M., Buehmann, D., Doumas, T., Goldberg, G., Graystone, P., Gunderson, J., Kelso, D., Rodgers, B., & Vanderheiden, G.

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THE DATA ROUTING MODULE: ACCESSING COMPUTER SYSTEMS WITH COMMUNICATION AIDS

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ABSTRACT

Past techniques allowing people with physical handicaps to access computer systems required modification of the terminal hardware and computer software. This required computer expertise and was expensive. Now an inexpensive, totally transparent and easy to install module allows physically handicapped people to use communication aids as alternate input or output devices with computer systems that use standard RS-232-C[1] terminals.

The Data Routing Module is a small box plugged into the cable between the terminal and the computer. Once the Data Routing Module is connected any communication aid with an RS-232-C output plugged to the Data Routing Module can act as an alternate input or output device without interfering with normal operation of the terminal and without requiring changes in hardware or computer software.

INTRODUCTION

Computers are becoming integral components of all aspects of education, employment, and daily life. This is especially significant for persons with physical disabilities, whose greatest opportunities for meaningful employment may lie in jobs that require a lot of interaction with computers. Therefore, for the physically handicapped persons who can not operate a standard computer keyboard it is necessary to develop an inexpensive method to interface communication aids to computer systems. To accomplish this the TRACE center is developing a module that plugs into the RS-232-C cable between a computer terminal and a computer. The Data Routing Module allows a person to use any aid that can output ASCII characters via the RS-232-C serial standard as an alternative keyboard to the one on the standard terminal. It also allows an alternate display device like a Braille screen to display what appears on the standard CRT screen.

The Data Routing Module routes data from the communication aid to the computer and to the terminal display. Data from the computer is sent to the terminal display and to the communication aid. Data from the terminal keyboard is sent to the computer and to the communication aid. This routing makes the aid transparent to the system. Our initial goals were to develop a device that:

1) would allow communication aids to act as alternate keyboards to the terminal.

2) could be installed without any modification to the terminal or operating system.

3) does not interfere with the normal operation of the terminal in any way.

4) would operate in full or half duplex mode.

5) could be sold inexpensively ($100 to $300).

FINAL SPECIFICATIONS

1. The Data Routing Module has three 25 pin D RS-232-C connectors.
   a. one female connector for the main computer
   b. one female connector for the terminal
   c. one female connector for alternate input devices (communication aids, etc.), or for alternate output devices (Braille displays, etc.), or for alternate devices with both input and output capability.

2. The Data Routing Module is designed so that in FULL DUPLEX data is routed:
   a) from the computer to both the terminal and the alternate device
   b) from the terminal to the computer
   c) from the alternate device to the computer

3. The Data Routing Module is designed so that in HALF DUPLEX data is routed:
   a) from the computer to both the terminal and the alternate device
   b) from the terminal to both the computer and the alternate device
   c) from the alternate device to both the computer and the terminal

4. The Data Routing Module allows the terminal to send and receive data from the main computer at all times whether or not a device is connected to the alternate device connector. This requires that the alternate connector assume a transparent state when not connected.

5. No hardware handshaking lines are implemented to the alternate device but all 25 RS-232-C lines are passed through from the computer connector to the terminal connector making the Data Routing Module completely transparent.

6. There is a provision for an optional SPST switch accessible on the top of the enclosure that selects either full or half duplex.

7. The Data Routing Module uses an active circuit with integrated circuit RS-232-C drivers (1488s) that have more than the minimum RS-232-C drive capability and handle baud rates up to 19200.

8. Power is provided from a standard UL approved direct plug-in transformer that can be obtained from either Zygo, Inc. or Prentke Romich Co.

9. There are 4 status Light Emitting Diodes (LEDs) one red and three green. The red LED indicates power. Each of the three green LEDs is associated with one of the three RS-232-C connectors. When an LED is on it indicates that an active RS-232-C device is properly connected to the input pin of the corresponding connector. The LED will blink continuously while data is being received on that pin.

10. The Data Routing Module is designed to be light and drop resistant. It measures 4.5" x 7.5" x 2.3" and weighs less than one pound. All three 25 pin D connectors and all of the LEDs are mounted directly on the circuit board.

DISCUSSION

Specifications 5 - 10 are elaborated below.

Specification 5: Hardware Handshaking

Most systems do not use hardware handshaking and of those that do there is no one standard protocol. Implementing just two hardware handshaking lines would double the amount of circuitry and implementing all the RS-232-C lines for handshaking would increase the complexity another 3 or 4 times. Therefore, hardware handshaking is not implemented for the alternate device connector. All 25 of the RS-232-C lines are connected between the computer connector and the terminal connector in order to implement any static status signals that may be present and necessary without active circuitry. This facilitates the ready condition without knowing how specific handshaking lines are being used in a particular system and makes the Data Routing Module completely "transparent".

Specification 6: Full and Half Duplex

Changing the Data Routing Module from full duplex to half duplex would require that a switch be added and an accessible switch would add to the cost significantly. 90% or more of the current systems use full duplex and as time goes on an even larger percentage will be full duplex. If the Data Routing Module were used on one system exclusively then it need be switched to the proper mode for that system only once; this could be done by the person who initially connected the Data Routing Module. Anyone who can plug in the 25 pin D connectors to install the Data Routing Module would be able to operate a standard switch so a special accessible switch would not be necessary. However, if the Data Routing Module were used with a modem and the handicapped user wished to communicate with different systems then s/he might need to switch modes and it would be necessary to make the switch accessible to the particular user.

The circuitry necessary to allow both full and half duplex is relatively inexpensive and since there are still a few situations where half duplex is necessary, it is included. However, the switch itself is optional. A custom switch can be added either by the manufacturer or by the user.

Specification 7: Passive VS Active Circuits

A commercially available device , the MS-3 Modem Splitter (available from the "Black Box Company" of Pittsburg, Pa and listed for $149 in their 1983 catalog), may work as a Data Routing Module in some situations, but it will not work for all situations because it is completely passive. It connects three RS-232-C connectors in parallel to one RS-232-C connector and includes diode isolation on the parallel output lines. Since the RS-232-C standard requires a driver to drive only one load and since in a Modem Splitter (used as a Data Routing Module) the driver would have to drive at least two loads it violates RS-232-C. Therefore, the MS-3 will not work with all systems but since it has no active circuitry it may be less expensive than an active circuit Data Routing Module.

Many typical IC drivers (such as 1488s) used on modern equipment can readily drive more than one load. As a result, many systems in actual use are already cheating on the RS-232-C standard by using multiple loads or longer cables that will only work with these "typical" drivers. Therefore, it is important for most Data Routing Modules to have "typical" drive capacity in order to work with these systems. In addition, if the aid (the alternate device) has minimum RS-232-C drive capability then an active Data Routing Module with a typical drive capability would be necessary to act as a signal booster as well as a Data Routing Module. Aids with minimum RS-232-C drive capability are common (some serial boards for Apple II computers). As a result, the Data Routing Module uses an active circuit design with RS-232-C drivers (1488s) that have typical drive capability.

Specification 8: Transformer Location

Power is provided by a transformer from a standard 120 v wall outlet. Serious consideration was given to locating the transformer in the enclosure in order to make the Data Routing Module self contained and easier to carry. The alternative is to use a UL approved direct plug-in transformer. Putting the transformer in the enclosure would have required that the entire Data Routing Module be approved by Underwriters Laboratories in order to be used in many clinical situations. UL approval would cost several thousand dollars initially and the manufacturer would have to continue to pay several hundred dollars each year to maintain UL status. In addition, the process of obtaining approval can be slow (from 6 months to several years). For these reasons and others, manufacturers contacted were very much against using an internal transformer. Therefore, a UL approved direct plug-in transformer is used for power.

We designed the Data Routing Module so that it will work with either the standard Zygo (Portland, Oregon) 12.5 v direct plug-in transformer or the Prentke Romich (Shreve, Ohio) 10 v Autocom direct plug-in transformer. This makes it easy for either company to manufacture the Data Routing Module. Because the power supply circuit is very tolerant of voltage variations the Data Routing Module can be inadvertently connected to any UL approved class 2 direct plug-in transformer (max voltage is 30 v rms) without damage to the unit or danger of fire. This is important since many UL approved direct plug-in transformers use the same connector and since they may have any voltage up to 30 v rms.

Specification 9: Human Factors/Status Lights

The Data Routing Module may be used in two different ways. Ideally there should be a Data Routing Module more or less permanently plugged into each terminal that the handicapped user needs to have access to. More likely, a handicapped user may occasionally have to take a Data Routing Module with her/him to access a remote terminal such as at a library. In this case the Data Routing Module will often be installed by inexperienced persons and it becomes very important to make installation appear to be and be as simple as possible in order

to make them willing to attempt it. In order to accomplish this we suggested the addition of three green lights, one for each connector, that would only light if the connector were properly inserted and the connected device's communication circuitry were on. In addition, each light would blink in an easily perceivable way when data was being received by the Data Routing Module from the device connected to the corresponding connector. We also suggested a red light that would light when the Data Routing Module was correctly plugged into a suitable direct plug-in transformer that was itself plugged into a live 120v AC outlet.

Because the Data Routing Module circuitry is relatively simple these lights could add significantly to the cost. When we pointed out that the retail cost for the Data Routing Module might be $150 without the lights and $225 with the lights (or some similar ratio) all of those polled including clinicians, outside computer experts, and members of COPH II said they thought the status lights would be worth the extra money. The reasons given include the following.
The status lights would:

1) help assure the person who connects the Data Routing Module that he/she is doing it successfully.

2) give the handicapped user confidence that they can find someone willing and able to connect them to a strange system.

3) provide immediate positive indication of a functional connection.

4) give the handicapped user an indication that the terminal connection and the computer connection that s/he can't see are still properly connected.

5) help identify systems where the terminal computer connections are consistantly miswired.

6) identify simple correctable problems such as a turned off outlet, loose connectors, bad cables, main computer down, or aid battery low.

7) help in explaining the nature and degree of a potential service problem over the phone to the manufacturer's service department in order to determine if the device should be sent back to the manufacturer for repair.

As a result, the Data Routing Module includes these status lights. Since a positive indication is desired to indicate a correct active connection the green LEDs were designed to be ON when the connection is good. However, this creates a problem in visibility because it is more difficult to perceive a normally ON light momentarily blinking OFF than one normally OFF that blinks ON. Also, at high baud rates (9600) it is always difficult to perceive the blinking that indicates data transmission. Therefore, to provide an easily perceivable; useful indication of data transmission the design uses a special circuit that makes the green lights blink about 4 times a second when data is received no matter what the baud rate is.

Specification 10: Human Factors/Mechanical

The fact that the Data Routing Module may sometimes have to be carried along and hooked up to an unfamiliar system places some further demands on the design. The enclosure is made of impact resistant plastic. This makes it lighter and more drop resistant than a metal enclosure and is less expensive. The Data Routing Module is relatively light weight compared to typical RS-232-C cables, so the connectors are located to provide the straightest cable run. The terminal connector and the computer connector were put on the back since these cables would normally lead off in that direction and the alternate connector was put on the front where the aid's cable can go straight in.

There are now available very inexpensive plastic circuit board mounted 25 pin D connectors that appear to be a rugged and inexpensive alternative to panel mounted metal connectors. Since using these connectors could save signficantly on the cost of the Data Routing Module (and other aids with a number of connectors) we decided to include them in our prototype design in order to test their ruggedness in an actual use. To save further on manufacturing costs all the LED status indicator lights were mounted on the board. The design requires only the direct plug-in transformer connector to be mounted directly to the enclosure.

CONCLUSION

The Data Routing Module appears to offer a simple, cost effective way for physically handicapped people to interface their communication aids to computer systems that use standard RS-232-C terminals. To test the actual viability of the Data Routing Module several prototypes are being placed with handicapped computer users for their evaluation. Prototypes are also being evaluated by the COPH II handicapped consumer group in Chicago, and by the Systems and Aids Clinic (California State University at Sacremento). Prentke Romich Co. (Shreve, Ohio) and Zygo, Inc. (Portland, Oregon), two prominent aid makers, are also evaluating prototypes for potential manufacture.

ACKNOWLEDGMENTS

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REFERENCES

1. EIA Standard, RS-232-C, August 1969, Electronic Industries Association, Engineering Department, 2001 Eye Street, N.W., Washington, D.C. 20006

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APPLICATION OF AN OPTICAL KEYBOARD FOR JOB-SITE ACCESS TO STANDARD COMPUTER SYSTEMS

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ABSTRACT - For individuals with severe motor disfunction, access to standard computers and computer systems necessary for some jobs can be difficult or impossible. Special low-fatigue techniques are available, however, which can provide transparent access to computer systems without requiring modification to any system software. Described is one approach now being used at the Government Accounting Office in Washington.

RÉSUMÉ - Certaines personnes souffrant de troubles moteurs sévères trouvent difficile, voire impossible, d'accéder à des ordinateurs ou des systèmes informatiques dont elles peuvent avoir besoin dans leur travail. Il existe des techniques peu éreintantes qui leur offrent un accès transparent aux systèmes informatiques sans que cela impose une modification du logiciel. On décrit ici la solution utilisée au Bureau de la comptabilité du Gouvernement à Washington.

INTRODUCTION TO THE PROBLEM

When I first joined GAO over twenty years ago, I had muscular dystrophy, an increasingly debilitating disease. At the time, it was only a minor impediment to me. I was able to work in the same environment with the same implements as my co-workers. Since that time, I have experienced a gradual, almost imperceptible loss of muscular ability. Today I require a power wheelchair for mobility, and experience fatigue from even light exertion such as typing or writing.

In order to expand job opportunities and reduce hand-writing tasks, I also moved over into the use of the GAO mainframe computers, and tasks revolving around the manipulation and statistical analysis of data gathered for GAO. Fatigue, however, was still a severe problem. Some low-fatigue mechanism was therefore needed which would allow access to the standard computers and computer systems at GAO. This access, however, had to be provided without modifications of any kind to the GAO equipment (leased) or the software systems (which were essentially inaccessible, and under constant external revision as well as use by multiple departments).

THE SOLUTION APPROACH

The approach taken was to develop a special optical keyboard which could be operated with head-pointing motions. This provided a low fatigue and fairly quick input technique. The optical keyboard was coupled with an abbreviation expansion routine to accelerate the effective rate of input. The output of this accelerated optical keyboard was then fed into a keyboard emulator module which plugged into the standard DEC VT-100 terminal (Digital Equipment Corporation). The keyboard emulator made the signals coming from the accelerated optical keyboard look exactly as if they had come from the VT-100's standard keyboard. It is thus impossible for DEC VT-100 or the mainframe computer to tell that the user is not typing on the standard keyboard. The VT-100 was chosen because it is the same terminal line being used by all of the other individuals at GAO. Thus, except for the optical keyboard, this "special terminal" looks exactly the same and functions in exactly the same manner as any of the other terminals in the office. The only actual difference in the operation of the terminal is that an auto-dialing modem was provided for this terminal. The modem is the same brand as used by all of the other terminals in the office. The auto-dialing feature was added, however, to allow the user to call up the mainframe computer directly from the "keyboard" of the terminal, rather than having to manipulate the phone by hand.

Except for two small custom hardware modules, all of the hardware used in the system is standard off-the-shelf hardware to maximize the replication and dissemination of the technique. The two custom modules (the optical headpointer and the keyboard emulator) are both general-purpose modules developed at the Trace R&D Center in Madison, Wisconsin, and are currently being transferred themselves to commercial production.

THE BASIC COMPONENTS

The basic components of the overall system are:

1) long-range optical headpointer.

2) Apple II computer, which provides the optical keyboard image, the feedback of the headpointing position, and the abbreviation expansion routines, and the keyboard emulator driver.

3) keyboard emulator for the proper computer/terminal (in this case, a DEC Model VT-100).

4) standard computer terminal (DEC VT-100) with auto-dialing phone modem.

5) standard mainframe computer running standard software.

The long-range optical headpointer used was developed at the Trace R&D Center at the University of Wisconsin. This pointer is approximately the same size as a magic marker, and works on the same principle as a lightpen. However, special amplification and signal processing is done such that the pointer can be used from as much as four feet from the screen, with one-pixel stability. As a result, the pointer can be attached to the user's head, and very precise feedback of the pointing motions on a television screen provided.

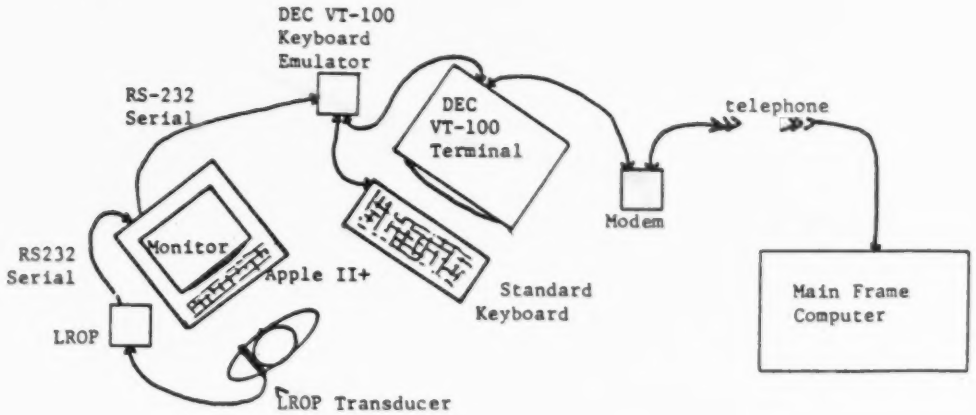
The output of the optical headpointer or lightpen is X and Y position on the television screen; this is sent via RS232 serial ASCII to the Apple (or any other) computer. The Apple computer presents an image of the keyboard on the screen, and moves a spot around the screen to correspond to the position being indicated by the long-range pointer. The effect to the user is as if he or she were pointing to the screen using a beam of light. Using this flowing dot, the user points to the various keys on the keyboard. The Apple computer notes when the user pauses on a key, and accepts those keys as keystrokes. The Apple computer also keeps track of the user's abbreviations and vocabulary. This allows the user to spell out words, phrases, and even commonly used sentences or paragraphs using very short 2- and 3-letter abbreviations. A 20,000-word spelling dictionary is also provided in the Apple to aid users who need but have difficulty accessing standard (paper) spelling dictionaries.

The output from the Apple then goes to the keyboard emulator module. This module accepts RS232 serial ASCII and puts out electrical signals which exactly emulate the signals from the VT-100's keyboard. The KEI (Keyboard Emulator Interface) Compatability Standard developed at the Trace Center is used to handle the codes for the non-ASCII keys on the VT-100 keyboard.

The rest of the system is standard terminal and computer hardware, and is used in the standard fashion.

CONCLUSION

As computer technology becomes more deeply involved in the workplace, technology can become either a means for helping handicapped persons or become another, perhaps even greater, barrier to their participation. The specific equipment and the general approach described show how it is possible for those with limited or no use of their hands to interact with and control standard computer hardware and software. This can open doors to both employment and social participation, and help disabled individuals realize their full potential.



TWO HEADPOINTING INPUT TECHNIQUES - A COMPARATIVE STUDY

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ABSTRACT - An ongoing empirical study comparing two headpointing technologies is described. Details of subject selection, research methodology and design and the configuration of the research instrument are provided.

RÉSUMÉ - Une étude expérimentale en cours, comparant deux technologies qui sont en train d'émerger, est décrite ci-après. On y donne les détails relatifs au choix du sujet, à la méthodologie et à la conception de la recherche, et à la configuration de l'appareil de recherche.

Background

For several years the Trace Center has been interested in developing and comparing input methods using the head as the bodily control site for input to a communication aid or computer. This interest grew out of clinical experience indicating that clients with athetoid cerebral palsy were much more accurate when pointing with an optical indicator than one might think when observing their use of a mechanical pointer (head stick or mouth stick).

Development efforts have resulted in the hybrid optical headpointer for the Express III (HPS-1, Prentke Romich Co.)[1] and in the LROP (Long Range Optical Headpointer; Gunderson, 1983)[2].

In 1978 Polhemus Navigational Sciences, Inc. developed an electromagnetic head tracking device, called the SPA-SYN, used by military personnel to aim weapons at targets. A 3-dimensional head position sensor and a sighting device is mounted on a gunner's helmet, and the target location is derived from the gunner's head position when the gunner looks at the target. Application of this technology to control computers for the handicapped seemed possible, the largest barrier at that time being portability and end-user expense (Schneider, 1982)[3].

Project History

P.N.S.I. (Polhemus) received funding from the Veteran's Administration in 1981 to act as contractors in developing the SPA-SYN technology as a prototype aid (SPA-SYN-COM). The Trace Center has been conducting an empirical study to determine which of several headpointing technologies and techniques work best for handicapped users.

At this writing, the project is in Phase II, the evaluation and testing of the various methods of headpointing or headpositioning. Twenty disabled subjects have been selected and pre-screened. They will play a series of video "games" which use different algorithms both in interpreting the pointing motion of the subject and in providing various types of feedback to him/her. (Subject testing is scheduled to begin in January, 1984.)

Activities to date have included developing a statistical approach and research design for the experiment, physically configuring the research instrument, and writing the software necessary for data collection, games protocol, targeting, etc.

Research Design and Analysis

The population of interest includes those individuals from age 8 to adult for whom: 1) speech is not a functional communication system or 2) access to keyboard devices is limited due to paralysis, weakness, incoordination, or absence of the upper limbs. Further, the population of interest is defined to include only those candidates for augmentative communication who attain satisfactory performance on a pre-test of head control.

Persons in this population exhibit widely varying degrees of involvement with their particular disability.

The impaired motor functions (which may or may not interfere with speech, but which do affect the control of the arms and hands in all of these people), can be divided into three categories. These categorical divisions are:

1) absence of control (paralysis, polio)

2) reduced effectiveness of control (myasthenia gravis, ALS, MS, other degenerative neuro-muscular diseases)

3) interference with control (athetoid, spastic or atonic cerebral palsy)

Data analysis will look at differences both within and across the three groups, employing the

Wilcoxin One-Sample Signed Ranks test .

A nonparametric statistical test was chosen because the assumption of normalcy was inappropriate for this population. There is no basis for believing that the distribution of performance scores even among all subjects with athetoid cerebral palsy (e.g., the same "group" in this study) will approximate a bell-shaped curve. The signed ranks test gives the greatest opportunity to capture existing trends in the data, even with large absolute inter-subject differences in performance scores. Such individual differences will not tend to cancel each other out using this method of analysis.

Two types of algorithms providing feedback to the user will be tested with each headpointing technology, actually giving four differently implemented tasks. One algorithm will include hysteresis, a simple way of averaging the user's continuous motion about the target. One will provide only direct interpretation of the user's pointing motions. The presentation order, and the sequencing of orders across 8 days of testing is randomly counterbalanced across subjects (twelve of the possible permutations of the four orders are randomly assigned to the 24 subjects.)

Subjects

The prevalence of the types of severe disabilities of interest in this study is relatively low in the general population, so that the distribution of potential volunteer subjects makes random selection logistically impossible. Nonetheless, the authors believe that 1) results both across subjects within groups, and 2) differences between groups will reveal relevant similarities. The authors maintain that these subjects are enough alike in their performance to be considered "typical" of their population group. Only replication of this study elsewhere will validate the assertion, however. Local subjects in Madison, Wisconsin, a group of several subjects at Gunderson Clinic in LaCrosse, Wisconsin and a group of 15 institutionalized children at the Illinois Childrens School and Hospital in Chicago will comprise the 20-24 subjects.

Research Instrument

The research instrument, which is based on the IBM Personal Computer, requires 2 serial input/output ports, a color graphics adaptor capable of 4-color medium resolution graphics, 576K bytes of memory, and 2 high-capacity disk drives. A 19" color monitor is used to present the targeting task. The software was developed in the language FORTH.

Data Collection

A computer program has been developed for capturing position and movement patterns of individuals using the long-range optical headpointer and the SPA-SYN device. The program presents the subject with a targeting task which simulates the process of selecting a word from a communication board. The communication board is represented by a grid on a color TV monitor. All but one of the cells in the grid contain the same object (foil). The cell containing the different object (target) represents the letter that the subject is trying to select. "Targets" and "foils" are not linguistically loaded, so that their use does not introduce confounding variables related to age, reading skill, or cognitive functioning. As the subject selects the target, the program moves the target location around the grid in a fixed pattern. Selection of a foil causes the target to appear in the center of the grid. This forces the subject to select the center cell when an error is made so that the "backspace" function is simulated. While the subject is playing this video game, the spacing of the cells of the grid changes so that information transfer rate is maximized. The information transfer rate (CITR) is computed as:

$$CITR = Bc * \log_2(N)$$

where CITR = corrected information transfer rate
Bc = (S-2*I)/T
S = total selections made
I = incorrect selections
N = available selections
T = time to make S selections

The program saves the following data each time a selection is made:

1. Target/foil selected
2. Number of foils selected
3. Number of targets selected
4. Time since last selection
5. Cell spacing

Results

By comparing these two headpointing technologies, we hope to quantify the trade-offs implicit in the further development of either system. The Long Range Optical Pointer requires a CRT display. High resolution LCD displays, however, are becoming standard on portable, battery-operated computers. The SPA-SYN technology could be used with the LCD displays, and could even provide active feedback. A limiting factor to further development of the SPA-SYN-COM at this time is probable end-user cost. The results of the current study will guide further development decisions so that resources can be directed to provide maximum benefits.

References

1. Prentke Romich. PRODUCT FLYER HPS-1.
2. Gunderson, J. A HEADPOINTING TECHNIQUE FOR USE WITH STANDARD COMPUTER SYSTEMS.
3. Schneider, M.R. DESIGN OF A NEW COMMUNICATION AID: SPA-SYN-COM.
4. Conover, W.J. PRACTICAL NONPARAMETRIC STATISTICS.

GENERIC KEYBOARD EMULATOR ARCHITECTURE FOR TRANSPARENT ACCESS TO STANDARD SOFTWARE BY HANDICAPPED INDIVIDUALS

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ABSTRACT - One very powerful method to allow handicapped individuals to access computers and standard software is the use of keyboard emulators. Different computers, however, use widely varying technologies, necessitating emulators which operate quite differently electrically. It is possible to capitalize on the functional similarities of the emulators to minimize the redesign necessary to create new emulators.

RÉSUMÉ - Les émulateurs sont des outils très puissants permettant aux handicapés d'accéder seuls à des ordinateurs et à du logiciel standard. Toutefois, il existe de nombreux ordinateurs différents qui font appel à un large éventail de technologies; il est alors nécessaire d'avoir des émulateurs dont le fonctionnement électrique est passablement différent. Il y a possibilité d'exploiter les similitudes fonctionnelles des émulateurs pour alléger la tâche de reconception des émulateurs.

INTRODUCTION

One of the principle difficulties in the use of computers by individuals with disabilities revolves around their inability to use standard computer software and operating systems. Although special software can be written which can accomodate any specific handicap, access by handicapped individuals must also be provided to the vast wealth of standard unmodified software. This is necessary both to provide access to the functions implemented in these standard software programs and to allow handicapped individuals to be integrated into regular education, work, and living environments which utilize computers and computer systems with standard software packages.

Currently, the most powerful technique for allowing access to standard software by individuals with physical handicaps is the keyboard emulator. The keyboard emulator is a module which connects between the computer's keyboard and the rest of the computer. The emulator itself does not interfere with the use of the standard keyboard in any way. It does, however, allow "keystrokes" to be sent from special communication aids, which it then passes on to the computer. The method it uses to pass the characters to the computer is such that it exactly imitates the standard keyboard's electrical signals. Since the emulator is plugged into the same point as the standard keyboard, the computer is completely unable to distinguish keystrokes being sent from the standard keyboard from those coming from the keyboard emulator. As a result, all input to the computer from the special device is exactly equivalent to keystrokes on the keyboard. All software written to operate with the computer's standard keyboard can therefore be operated by handicapped individuals using any one of a wide range of adaptive communication or control aids.

THE PROBLEM

Because the emulator must exactly imitate the keyboard, however, the emulators must be electrically tailored to exactly match the characteristics of the keyboard for each specific computer they are to be used with. This tailoring includes both electrical and physical modifications. As a result, keyboard emulators generally need to be designed separately for each computer. Even the Apple II and the Apple IIe require different keyboard emulators, since they have keyboards which are electronically different. As a result, there are relatively few computers for which keyboard emulators are commercially available, and the delay between the introduction of a new computer and the availability of an emulator for it can be quite lengthy.

THE APPROACH TAKEN

In order to alleviate this problem, to provide a mechanism for more timely development of new keyboard emulators, and to provide a mechanism for lower-cost development of keyboard emulators for new computers, a program was initiated to develop a generic architecture for keyboard emulators. This approach consisted of two parts:

1) the development of a single-chip, microprocessor-based emulator architecture which could be easily adapted to create keyboard emulators for new computers as required.

2) the development of a standard code for communicating with keyboard emulators and handling keyboards having differing numbers of keys and a variety of special non-ASCII keys.

The emulators themselves are all designed to take

is done to maximize their ability to be used with a wide variety of communication and adaptive control aids. The output of the emulators, as well as their packaging, is customized for the particular computer being used. For computers with external plug-in keyboards, such as the IBM PC and the DEC VT-100 series terminals, the keyboard emulator is packaged in a small plastic box which plugs in between the keyboard and the CPU. For computers with built-in keyboards, such as the Apple and the Atari, the emulator is usually put on a small PC board which mounts directly inside the computer.

THE GENERAL HARDWARE ARCHITECTURE

The largest problem with keyboard emulators is the extremely wide variety of communication formats which exist between a computer and its keyboard. In an Apple II+, for example, this format consists of an 8-bit parallel bus with a separate reset line. In an Apple IIe, it consists simply of a shorting of row and column lines in a large 8x10 matrix, plus 6 additional lines. In other computers, an x-y matrix is again used, except that it is read both in an "any key down" fashion, with all lines tied low, as well as individual row-column combinations. The IBM keyboard actually has its own microprocessor and communicates with the main computer using a clocked serial line. The DEC VT-100 terminals also use a serial line, but with bi-directional communication and power being carried on a simple 3-pin connector.

In order to accomodate these widely varying hardware formats, an architecture was required which was very flexible, especially the interface with the computer. At the same time, these various keyboard emulators all were performing the same basic function, and therefore had many functional sub-components which were identical. Rather than using a discrete component approach, as had been used in all commercial keyboard emulators to date, the project opted for a single-chip microprocessor-based approach. This not only allowed for much more flexibility in the design of the emulators, but also provided the processing necessary to handle the multiple simultaneous non-ASCII key closures which are required on many of the newer computers. (For example, the new IBM requires a control-scroll-lock to break from a program, a control-alternate-delete to reset the computer, etc.)

The 8748/8035/8049 family of microprocessors was chosen for the application, due to their widespread availability, low cost, and availability in both MOS and, more recently, in CMOS versions. Each of the emulators uses the same input circuitry (for interfacing to communication aids), the same input software routines, the same translation tables, and the same multiple simultaneous key activation routines. Only the packaging and the electronics to actually the emulate the key closures (and the multi-plexing of the standard keyboard, where required) need be redesigned for newer keyboards. Although these aspects are not trivial, reducing the keyboard emulator design to these components can considerably reduce the design time for keyboard emulators for new computers. In one instance, a keyboard emulator for the Apple IIe was designed and taken through finished artwork in about 6 weeks, and mailed directly to a company that put it into commercial production.

DEVELOPMENT OF A KEYBOARD EMULATOR COMMUNICATION FORMAT

The second aspect of the project was to develop a standard format for communication between the handicapped user's aid and the keyboard emulator. The major problem arises from the fact that the communication aids only put out the standard ASCII characters. Most computer keyboards, however, have many non-ASCII keys. Included are such keys as "SHIFT", "FUNCTION" keys, "SCROLL LOCK", "ARROW" keys, "RESET", etc. As a result, it is not sufficient for the emulators to simply accept ASCII characters and "depress" the corresponding key on the keyboard. Some mechanism was needed to specify these non-ASCII keys as well.

In order to handle this, a special standard communication format was developed in conjunction with the Standards Project at the Trace Center. An ESCAPE sequence was used to specify the names of these other, non-ASCII, keys. Those keys which appear on a large number of different keyboards (e.g., back arrow, delete, shift, etc.) are given standard names. This is done so that an individual can move his or her communication aid from an IBM to an Apple to an Atari, etc., and activate the equivalent key on these keyboards even though the legend on the key may vary slightly. For those keys which are strictly unique to a given computer, the legend on the key is used. Provision is also made so that the keyboard emulator can be instructed to hold down multiple keys while other keys are struck. For those communication aids which have custom vocabulary capability, the entire key sequence for any of the special keys on the computer keyboard could be programmed into a single square on the communication aid; thus, selecting a SCROLL LOCK or RESET square on the communication aid would cause the appropriate sequence of codes to be sent to the keyboard emulator, which would result in a simulated depression of the SCROLL LOCK key or the CONTROL-ALTERNATE-DELETE keys (for reset) on the computer keyboard.

CONCLUSION

So far, the architecture has worked well, and has been used to develop keyboard emulators for the Apple IIe, the DEC VT-100, and the IBM PC. Emulators for the Atari, Commodore, Acorn, and PCjr are currently underway.

A MULTIPURPOSE STAND ALONE EXPANDED KEYBOARD FOR THE DISABLED

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ABSTRACT - Passive matrix type expanded keyboards are reviewed and the development of a multipurpose stand alone matrix keyboard is described. The circuit and mechanical construction is explained and the use with the Trace Center's BLISSAPPLE program is described.

RÉSUMÉ - On revoit ici des claviers matriciels passifs surdimensionnés, et on décrit l'élaboration d'un clavier matriciel autonome à vocation multiple. On présente la configuration mécanique et électronique de celui-ci, de même que l'utilisation du programme BLISSAPPLE du Trace Center.

Introduction

A number of expanded keyboards have been developed in the past in the Rehabilitation Engineering Laboratory in the School of Rehabilitation Medicine at the University of British Columbia. The principle of the design of these keyboards is as follows:- a series of vertical bronze rods is stapled to a 3/4 inch plywood baseboard and foam rubber sheet is glued between these rods. A plastic cover rests on the foam and on the back of this cover is a second set of bronze rods, this time running horizontally. Pressing on the top plastic cover depresses the foam and allows the rods to touch. A grid of appropriate symbols is silk screened on the top of the plastic cover and connections to the two sets of rods are brought out to a suitable plug. These expanded keyboards have been built for a number of devices including the Apple II+, the Apple IIe, the Timex/Sinclair 1000, the Casio organ and the Texas Instruments Speak and Spell, Speak and Read and Speak and Math series. A special expanded keyboard called the Activity Board was also developed for use with electric toys. The thickness and width of the foam which separates the crossed rods can be varied to determine the sensitivity of the switch contacts. The very small contact area and corresponding high contact pressure, creates an efficient self cleaning switch. This keyboard design has been reported earlier (References 1 - 5) and has proved to be very reliable and noise free.

The BLISSAPPLE program, developed at the Trace Research and Development Center allows handicapped children to communicate with Blissymbols. The vocabulary is completely user determined from a library of over 1,400 pre-programmed symbols and selection of the symbols can be made by a variety of different input methods. In most of the cases the Blissymbol is identified by a number, requiring the user to enter this number by one of the input methods. If the user is accessing 500 symbols, then he must either remember the number (of up to three digits) associated with the symbol or must look it up before he can enter it. A common way of achieving this is to have a 500 square Bliss board within visual range of the user. The numbers associated with the symbols are then written under the symbols on this board. Because the board is large it cannot be placed very close to the user, making the numbers difficult to read, particularly by persons with below normal vision.

Preliminary work

The BLISSAPPLE program has a provision for direct access to the symbols from a matrix type keyboard. A circuit to scan the matrix can be built on a plug-in card and inserted into an Apple computer peripheral expansion slot. This circuit must either provide access to the Apple buss or must in turn be connected to a parallel interface card, using up yet another expansion slot. Such a system with 220 squares was built at the School of Rehabilitation Medicine at the University of British Columbia and has been in use at the Vocational and Rehabilitation Research Institute in Calgary, Alberta for the past year. This board uses a 16 X 16 folded matrix of bronze rods on one inch centers, giving a 22 by 10 array on a board 14 inches by 28 inches and 3/4 inch thick.

Present work

Considerable discussion between the authors spanning a period of a year has led to the decision to produce a stand alone expanded keyboard. This keyboard has 512 squares on 7/8 inch spacing using a 32 X 16 matrix. The mechanical construction of the keyboard has not be changed from the earlier versions, however the electronic concept has completely changed. The earlier versions, described in the references and the first version of the expanded Bliss board, all consisted of a simple matrix inside the board, requiring no power to the board. All the electronics was contained in the host device. In the new design, all the electronics is contained inside the expanded keyboard which produces an output of serial ASCII on a standard RS 232 connector. With the advent of small battery operated computers, the expanded keyboard can be used for very many uses other than for just the access to the BLISSAPPLE program. Also if the keyboard is available, it will stimulate others to write programs similar to the BLISSAPPLE for the small portable computers.

The circuit

This was entirely the work of Dave Kelso and is a CMOS system based on an 80C35 microprocessor and a program stored in a 27C16 EPROM. It operates from virtually any commercially available power supply module, either AC or DC from 6 to 30 volts. On later models it is planned to include a battery compartment to allow the unit to be operated independent of an external power supply. The whole circuit is mounted on a 2 inch by 14 inch board which fits inside the expanded keyboard. Connection to the host computer or device is achieved by means of a standard RS 232 interconnect operating at 1200 baud. The 27C16 EPROM can be programmed with numbers, words or phrases or even commands. In the case of the Apple computer, the user must have a serial card plugged into one of the peripheral expansion slots to accept an RS 232 input from the expanded keyboard. Many of the new battery operated computers such as the Radio Shack Model 100 or the Epson HX 20 have built in RS 232 input circuitry. For use with the BlissApple program a keyboard with 512 squares is used. The EPROM is programmed so that the top left corner of the matrix sends a 1 and a carriage return and a line feed, the next square a 2 and so on reading from left to right and top to bottom so that the bottom right hand corner sends 512 and a carriage return and line feed. An overlay with the required Bliss symbols is placed on the keyboard and the squares programmed accordingly.

The expanded keyboard is available from:-
EKEG Electronics Co Ltd.,
P.O. Box 46199, Sta. G.,
Vancouver, B.C., Canada, V6R 4G5
(604) 685-7817

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References

1. Gloet, M. "Expanded Keyboards for Electronic Learning Aids, Proceedings of the 5th. Annual Conference on Rehabilitation Engineering, Houston, Texas, Aug 1982. p 22.

2. Graystone, P. "Microcomputers and the Disabled - the B.C. Connection", in Computers and the Handicapped pp 50-62, Published by the National Research Council - Ottawa, June 21-24, 1982.

3. Graystone, P. "Vocational Rehabilitation of High Level Quadriplegics by means of the Apple II Computer", Proceedings of the 5th. Annual Conference on Rehabilitation Engineering, Houston, Texas, Aug 1982 p 42.

4. Graystone, P. "Computer Interfaces for Severely Disabled Persons", Proceedings of the 5th. Annual Conference on Rehabilitation Engineering, Houston, Texas, Aug 1982 p 68.

5. Graystone, P. "Special Computer Interfaces for the Vocational Rehabilitation of the Severely Disabled", IEEE Computer Society Workshop on Computing to aid the Handicapped. Virginia, Nov 1982.

6. Silverman, H. and Kelso, D. "The Blis-Com: a Portable Symbol Printing Communication Aid." Proceedings of the 4th Annual Conference on Systems and Devices for the Disabled, Seattle , Wash., June 1-2 1977.

7. The Talking Blissapple, users manual, the Trace Research and Development Center 1983

A HIGH-EFFICIENCY FLEXIBLE KEYBOARD INPUT ACCELERATION TECHNIQUE: SPEEDKEY

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ABSTRACT - A general-purpose string substitution algorithm has been developed which can increase the input rate to 200-300% of the standard input rate on a standard 60-key keyboard, with higher rates for keyboards with a larger number of keys. The algorithm is flexible enough that it can also implement any abbreviation expansion technique, as well as many level and encoding techniques, as subsets of itself.

RÉSUMÉ - Un algorithme universel de substitution de chaînes a été élaboré avec les résultats suivants: la vitesse d'introduction avec un clavier standard de 60 touches est plus rapide de 200 à 300 %, et elle est encore plus rapide pour les claviers comptant plus de 60 touches. La souplesse de cet algorithme est telle qu'il est possible de mettre en oeuvre toute technique d'extension d'abréviations et des techniques de codage au niveau que l'on veut; ces techniques constituent des sous-ensembles de l'algorithme.

INTRODUCTION

Standard English spelling, in an attempt to be semi-phonetic, uses many more letters to "spell" words than is necessary to make them unique from each other. A person's "typing" speed could thus be increased if the unnecessary letters were simply omitted, or the words were spelled in shorter but still unique fashions. Unfortunately, this would make it difficult for individuals not familiar with the contracted form to read the text. With modern computers, however, it is a simple matter to "teach" the computer what the abbreviations and expansions are, and to have the computer automatically translate the contracted forms into full-length words as they are entered. It would not be necessary or even appropriate to contract all words that might be used. Very commonly used words, however, and words which are long or difficult to type, would be prime candidates for contraction.

Such a speed-typing technique could be of great benefit to handicapped individuals. With the particular algorithm described here, it is possible to increase the speed to between 200% and 300% of the normal typing rate when using a standard keyboard (approximately 60 keys). For aids or keyboards which have a larger number of keys, even greater gains are possible.

PAST WORK IN THE AREA

Because of the advantages and straightforward nature of abbreviation expansion, a number of approaches have been proposed in the past. In one scenario, abbreviations were all terminated with some type of special terminator character. For example, the "." could be used, or a special "EXPAND" key could be used. With this technique, the individual would type out the abbreviation and then hit the expansion key. This approach yielded 26 two-keystroke abbreviations (a single letter plus the expand key), 676 three-keystroke abbreviations (two letters and the expand key), and 17,576 four-keystroke abbreviations. It should be noted, however, that many of these abbreviations would not be particularly readable, since they would result in such unlikely abbreviations as "QXX expand" or "QQP expand". A second approach used the numerals to provide a self-terminating ten-branch abbreviation expansion technique (Kelso & Vanderheiden, 1982). With this technique, codes were comprised of zero or more letters, ending with a numeral. Thus, the codes would look like "1", or "A1", or "BJ5". Whenever the number was encountered, the system would immediately know that an abbreviation was being typed in, look it up, and replace the abbreviation with the expansion. To type regular numbers, the abbreviations feature would simply be turned off. With this approach, the number of short codes was significantly increased. There were 10 one-keystroke abbreviations, 260 two-keystroke abbreviations, 6,760 three-keystroke abbreviations, and better than 175,000 four-keystroke abbreviations. Once again, number of nonsense abbreviations would still appear. The number of nonsense abbreviations in the short keycodes, however, would be smaller.

THE UNUSED INITIAL N-GRAM EXPANSION TECHNIQUE
(SPD-KEY Translation Technique)

The proposed expansion algorithm is believed to be the most efficient possible abbreviation expansion routine. One reason for this is that all of the other abbreviation expansion routines are subsets of it. In addition, it provides greater flexibility and the greatest number of short codes.

With this approach, anything can be used as an abbreviation, as long as it is not itself a word or the initial letters of a word which the individual will want to be using. For example, the following are all legal abbreviations: "BT", "B4", "BTW", "ABV", "R2D2", "BR ", "G.V." and "GV".

In the above examples, you will note that none of the letter pairs or letter sequences are the legal beginnings for any word. The letters "BR" would be a legal word beginning, and therefore should not be used as an abbreviation. In the above list, however, you will note that the abbreviation was B-R-space. Since no words begin with a B, followed by an R, followed by a space, this would be a legal abbreviation. Please note

in this case, however, that this is a three-letter abbreviation, not a two-letter abbreviation, since hitting the space bar constitutes a keystroke. Similarly, hitting a "." or a special character would also be a third key. Other codes, such as "BRT" and "BRK", could also be used at the same time as "BR ", and would be just as efficient.

A special "rebreviate" key is also provided, greatly enhancing the function, power and speed of SPEEDKEY. The rebreviate key causes any expansion to instantly be transformed back to its contracted form. With the rebreviate key, it becomes possible to use character sequences which may show up as the beginnings of (rarely-used) words. For example, "PN" could be used as an abbreviation for "PHONE" without requiring a trailing space. This would give a very convenient 2-key abbreviation, but would still not outlaw the use of "PN" to spell "PNEUMONIA", in the rare cases where it comes up. The individual would simply type "PN", and the word "PHONE" would show up; hitting the rebreviate key would return it to "PN", and the user would continue to spell out "EUMONIA". The rebreviate key can also be used immediately before typing an abbreviation, and the algorithm will automatically skip over the next occuring expansion. For example, the individual could have hit the rebreviate key first, and then typed "P-N-E-U-M-O-N-I-A". When the "PN" was encountered, no expansion would be made. Striking the rebreviate key twice in succession automatically turns off the abbreviation expansion function until the key is struck a third time. Thus, the abbreviation expansion routine can be totally disabled, easily, at any time.

One very powerful consequence of the rebreviate key is that the numbers (and other special symbols) on the keyboard can also be used for words such as "the", "you", "to", "and", "will", "that", "is", "have", "what", etc., so that these frequently used words can be activated with one keystroke. This is important, since more than 20% of all of the words spoken and 15% of the keystrokes can be accounted for by the most 10 most frequently used words in a person's vocabulary. The numbers (and other symbols) can still be used in their traditional form when required by simply hitting the rebreviate key before the first number in a series, or hitting the rebreviate key twice to disable Speedkey when extended or frequent numbers are going to be used. In general, however, the numbers are used a very, very small portion of the time compared to the 10 most frequently used words. As with all aspects of Speedkey, however, an individual may choose to utilize the number keys for abbreviations, or may choose not to use them, entirely at his or her discretion.

Another major feature of Speedkey is the "prefix" key. With this key, any letter or letters can be automatically to the front of whatever is being typed, before it is looked up in the memory of the unit. For example, if an * key is pushed, and then the prefix key, all abbreviations will be looked up with an * appended to the front. This technique can be used to easily "change" the expansions for all of the abbreviations when special occasions arise. For instance, there may be some applications or situations where an individual need only respond using one of 10 or 20 responses. The individual could then key these into memory as two-character abbreviations consisting of an asterisk plus any single letter or number. Later, whenever he needed to access these, he would simply hit "*", then the "PREFIX LOCK" key. Thereafter, each time he struck a number or letter key (a single keystroke), the desired response would come forth. Hitting the PREFIX key again would turn off the function. In this fashion, special vocabularies as well as "levels" can be implemented with Speedkey. If desired, certain abbreviation/ expansion pairs can also be designated as "universal"; thus, they will always work in their standard fashion, even if a prefix is invoked. In this case, the computer will first check the list with the prefix added, and, if it finds no item, will then look for universal words without the prefix.

Comparing this technique to the previous approaches: with Speedkey on a standard 60-key keyboard, one would have the potential for 10 to 14 1-keystroke abbreviations, 950 2-keystroke abbreviations, and 4,500 3-keystroke abbreviations, etc.

EXAMPLE

Text:

> Dear sirs,
>
> I was very happy to hear from you on your plan to develop a communication aid for handicapped individuals.

Speedkey strokes: (slashes added here for clarity)

> ds/1/w5/vy/hy/2/hr/fm/3/o /yr/pln/2/dv/9/cm/ a2/4/hc/idv/BACKSPACE.

Abbreviations are always interpreted as beginning following a space. The space may be typed in from the keyboard, or come from the previous expansion. The efficiency of the system is entirely dependent upon how much the individual wants to utilize the features. A gain of about 200% of normal typing can be achieved by using short abbreviations for only the first 100 most frequently used words. This gain can be increased to around 300% of normal for general text, and higher for text utilizing words or phrases common to the individual. In the above example, slashes are used to indicate points where automatic expansion would take place.

Noting that the salutation includes the comma, carriage returns, and indent, and that the other abbreviations include the trailing spaces, this is a reduction from 123 keystrokes to 38 keystrokes, or an increase of approximately 310% of normal rate. The text on the screen, of course, would only appear in its fully expanded form; thus, message receivers and the users themselves would be looking at the output as if it had been typed out.

Full implementations of the Speedkey technique are currently underway by the Trace Center and other research groups. Programs which utilize Speedkey should be available within six months for at least the Apple, the Epson HX-20, and the IBM PC computers.

DEVELOPMENT OF A SET OF INTERNATIONAL COMMUNICATION AIDS COMPATIBILITY STANDARDS PROPOSALS (ICAC STDS)

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ABSTRACT - The paper introduces the development of a set of proposed compatibility standards for electrical communication aid devices. These compatibility standards proposals are primarily aimed at electrical communication aid devices for conversation, writing and computer access. The paper briefly describes each of the standards being developed.

RÉSUMÉ - L'objet de cette communication est d'exposer l'élaboration d'un ensemble de normes de compatibilité, qui a été proposé pour les aides de communication électriques. Ces propositions de norme visent principalement les aides de communication servant à la conversation, à l'écriture et à la communication avec un ordinateur. Chacune des normes en cours d'élaboration est décrite succinctement.

The TRACE Center is developing a set of proposed compatibility standards for electrical communication aid devices for conversation, writing, and computer access in conjunction with a group of interested manufacturers, clinicians, and researchers. Our goal is to reach a consensus on compatibility standards proposals and then get these proposals formally adopted by national and international standards organizations.

Purposes of Compatibility Standards

Many of the switches and controls used to operate electronic communication aids are functionally identical, and should be interchangeable. However, different manufacturers have selected different connectors, electrical formats, and logical formats. This makes it difficult for clinicians and users of aids to connect controls to an aid from a different manufacturer to configure a system appropriate to the person. It also reduces the market for these devices and forces manufacturers to provide the entire aid system.

The purposes of the proposed compatibility standards are:

1) to help provide appropriate and effective augmentative communication systems to anyone who needs them
2) by allowing electronically naive users, supporting persons, and service delivery persons to configure aid systems from components from different manufacturers
3) by allowing functionally appropriate devices from any manufacturer to be interconnectable and compatible with devices from any other manufacturer.

During the past year we have decided that compatibility for communication aids will be facilitated by the development of separate standards for functionally distinct situations. This makes each separate standard simpler and easier to implement and will make it easier to get the necessary consensus, which is the main test of a compatibility standard. We are currently working on the following compatibility standards proposals:

1) SET Compatibility Standard (Simple Electrical Transducer Compatibility Standard proposal)

Purpose: The SET Compatibility Standard is designed to provide for compatibility of simple electrical transducers and communication aids from different manufacturers .

Scope: The SET Compatibility Standard is meant to cover the connection between simple electrical transducers (switches, potentiometers, and rheostats) and communication aids. More sophisticated transducers such as EMG transducers can be used with the SET Compatibility Standard if they emulate one of the simple transducers.

2. SETSC Compatibility Standard (SET Serial Conversion Compatibility Standard proposal)

Purpose: The purpose of the SETSC Compatibility Standard is to provide a standard way to use adaptive SET controls with commercial portable computers through a standard RS-232C input port. This is done by providing a standard serial data format for transmitting simple electrical transducer information. This allows standard SET to RS-232C converters to be developed and allows standard software routines for processing input.

Scope: The SETSC Compatibility Standard proposal allows information from switches and pots to be transmitted on a single RS-232C serial channel simultaneously. This standard is also used for sending position information from long-range light pens and other devices that send X-Y coordinates.

3) ISA Compatibility Standard (Input Selection Array Compatibility Standard proposal)

Purpose: The purpose of the ISA Compatibility Standard is to provide for compatibility between input selection array transducers (such as large array keyboards) and communication aids.

Scope: The ISA Compatibility Standard is meant to cover Input Selection Array devices such as selection array keyboards (keyboards that are meant for one-at-a-time selection by location), scanning panels that can output a discrete selection after interacting with the user through a simple switch, and other devices that allow the user to make a single selection at a time from a displayed array of selections.

4. KEI Compatibility Standard (Keyboard Emulator Input Compatibility Standard proposal)

Purpose: The purpose of the Keyboard Emulator Input Compatibility Standard proposal is to provide a standard electrical and data input format for keyboard emulators. This will make it possible for an aid that can produce the Keyboard Emulator Input Compatibility Standard format to work with any standard keyboard emulator and thus work with any computer that has a standard keyboard emulator installed.

Scope: The KEI Compatibility Standard proposal is meant to cover the connection between a communication aid and the keyboard emulator for a computer running standard software. Keyboard emulators are devices designed to accept electronic data input and to introduce that data into a computer running standard software in such a way that it is indistinguishable from data input on the keyboard. The form of the data input to the keyboard emulator is the focus of the KEI Compatibility Standard proposal (the output of the keyboard emulator will always be specific to a particular computer and therefore not standardizable).

5. KEIMC Compatibility Standard (Keyboard Emulator Input Morse Code Compatibility Standard proposal)

Purpose: The purpose of the Keyboard Emulator Input Morse Code Compatibility Standard is to allow people using a three state sequential code (i.e. International Morse) to effectively communicate and to access computers.

Scope: The KEIMC Compatibility Standard is a superset of international Morse code. Using a three state sequential code it will produce the complete ASCII character set, common non ASCII keys such as arrow keys, and the special KEI functions such as "HOLD" for emulating key combinations.

6. SBC Compatibility Standard (Subsystem Bidirectional Communication Compatibility Standard proposal)

Purpose: The purpose of the SBC Compatibility Standard is to make it possible to design aids in a modular fashion to reduce the cost of the aid system, increase the lifetime of the aid, make the system more tailorable to the needs of the user, and reduce the skills required to properly specify, apply, install, and maintain the system.

Scope: The SBC Compatibility Standard is meant to cover bidirectional communications between communication aid subsystems such as a portable main processor, input display, output display, printer, voice output subsystem, environmental controller, modem, and wheelchair controller.

We hope that anyone developing or manufacturing devices covered by these proposals will contact us about them.

A PORTABLE COMPUTER-BASED WRITING, CONVERSATION AND COMPUTER ACCESS AID FOR SEVERELY MOTOR IMPAIRED INDIVIDUALS

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ABSTRACT - This portable communication aid is designed to provide basic language capabilities to severely motored impaired individuals in educational and vocational situations. The aid can be used for writing, conversation, and, with the use of keyboard emulators, access to standard computers.

RÉSUMÉ - L'aide de communication portatif que voici a été conçu afin d'offrir des fonctions de langage de base à des personnes affligées de troubles moteurs sévères, exploitables à l'école ou à leur travail. Ils peuvent s'en servir pour écrire, converser, ou communiquer avec des ordinateurs standard par l'intermédiaire d'émulateurs de clavier.

INTRODUCTION

Three of the major communication problems for non-vocal severely motored impaired individuals are conversation, writing and access to standard computers. The ability to converse and write is necessary for a child to enable him or her to receive a education comparable to his non-motor impaired peers in the same classroom. Conversation is important for developing expression skills, asking and answering questions, learning social interaction, and participating in classroom activities and discussions.

Writing has often fallen into the shadow of conversation, and been a secondary consideration in language intervention. This concept is changing, though, (Vanderheiden, 1983) as the importance of writing in education becomes clear, and handicapped children develop better language skills. Writing is required for a variety of normal classroom activities such as independent study, homework, testing, workbooks and the development of expressive writing skills.

Computers are being used in schools for two purposes. The first is to introduce students on how to operate and program computers, and the second is to facilitate the learning of a particular subject such as math, English, and science. Severely handicapped children also need to participate in these uses of computers. To do this they need to be able to use the same computers and programs as the other children in the classroom, even though they may not be able to type on the standard keyboard (Vanderheiden, 1982).

FUNCTIONAL DESCRIPTION

The EWCCAA (Electronic Writing, Conversation and Computer Access Aid) is being designed to meet these three basic communication needs. This aid has three separate parts: an input interface, amplification of selections, and the output function.

The EWCCAA is currently based on a EPSON HX-20 portable lap-held computer, but can be adapted to other computers as well (DeMasco and Foulds, 1982). The HX-20 has many of the features needed in portable communication aids. The HX-20 has rechargable batteries that provide continuous operation for up to 50 hrs. The 4 x 20 character LCD display provides a means for providing a correctable piece of "paper" to meet basic writing needs. A 24 column printer is used for generating a permanent copy of text the user has entered. A 50K micro-cassette drive provides a means of storing and retrieving text and backing up a users abbreviation expansion vocabulary.

Input Interface

The input interface is the part of the aid that the user interacts with to control the aid. Initially there will be three input techniques which can be used with the aid: the existing keyboard, external keyboards (large and small), and morse code. The existing keyboard technique uses the built-in keyboard of the HX-20. The keyboard is converted to a single-finger keyboard so that the user isn't required to hold down two keys simultaneously, which is normally necessary for generating shifted or control characters on standard keyboards.

The external keyboard (Graystone, 1982) is also a one-finger keyboard, similar in operation to the built-in keyboard. The external keyboard is a completely independent self-contained keyboard with a serial output, and typically has larger or smaller keys than the standard keyboard. These smaller or larger keyboards can be more selection information is formatted with the ISA (Input Selection Array) Standard for coding key selection information into a serial data format (Rodgers and Gunderson, 1984). The ISA standard is part of the International Communication Aids Compatibility Standard (ICAC).

The morse code input is a two switch auto keying input technique similar to traditional

morse code. The keying patterns have been enhanced to allow the generation of the entire ASCII character set (the ASCII character set is the standard set of characters used with computers).

Amplification

The amplification part of the aid increases the effective selection rate of the user. The particular amplification technique used in the EWCCAA is Speedkey. Speedkey is a very general purpose technique which converts a preprogrammed sequence of characters into another sequence of characters. The conversion of the character string is automatic, eliminating the need for an expand key found on some systems which thus require an extra user selection. An example of a speedkey entry would be using the character string "dfn" to represent the word "definition ". As soon as the characters "dfn" are selected the characters would be replaced by the expansion "definition ". The vocabulary items are completely programmable by the user to meet their particular communication requirements.

Speedkey can be used to develop both abbreviation expansion and level techniques. The level system can be implemented with a prefix function which attaches to the beginning of each character sequence a prefix for the purpose of looking up expansions. The prefix is functionally the same as changing levels because only abbreviations starting with the prefix can be selected.

Output Functions

There are five major output functions: worksheet, notebook, keyboard emulator, printer and speech synthesizer. The worksheet function is the user's pencil and paper and allows the user to enter and edit text. The worksheet has two pages of text, with each page holding approximately 2000 characters. The notebook provides a means to store and retrieve single worksheet pages of text. The page is stored on the cassette tape unit of the Epson and a approximately 20 pages of text can be stored per tape.

The EWCCAA will also be able to drive keyboard emulators using the KEI (Keyboard Emulator Input) standard which is a part of the ICAC. The keyboard emulator can be used directly with the output of speedkey or from the worksheet by transfering the worksheet text to the emulator.

The printer and the speech synthesizer functions can also be used directly with speed key, or from the text on worksheet. The printer and speech synthesizer have slightly different control routines because of their different functions and uses.

CONCLUSION

The objective of this project is to provide a child or adult with a means to participate in normal classroom and vocational situations. The EWCCAA provides the individual with a means to perform the basic communication functions required in both these settings along with the ability to work independently. By using only standard hardware, it is possible to provide these functions for a half to a third the cost normally associated with this type of aid, and move the aid to market in months rather than years.

REFERENCES

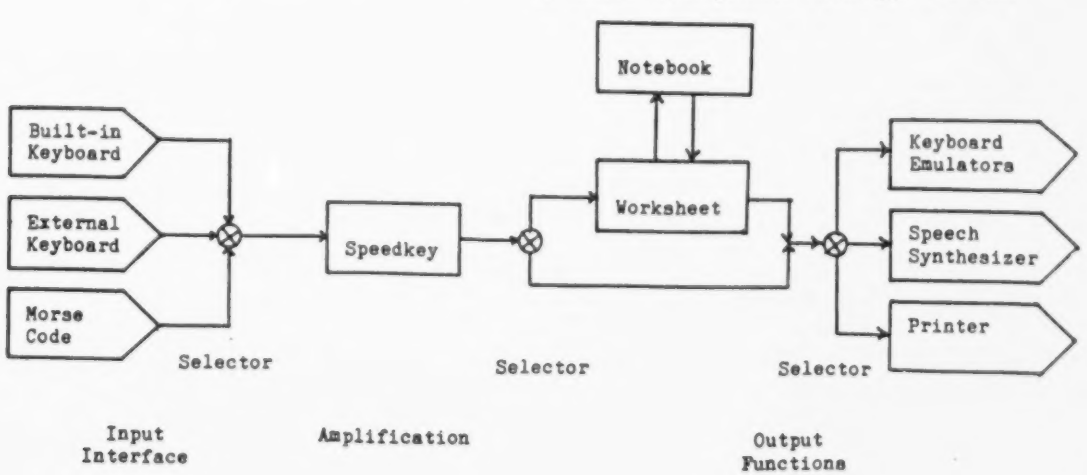
Demasco, P., and Foulds, R. A new horizon for nonvocal communication devices. BYTE, Vol. 7, No. 9, September 1982, pp. 166-182.

Greystone, P. Special computer interfaces for the vocational rehabilitation of the severely disabled. Proceedings of the IEEE Workshop on Computing to Aid the Handicapped, November 4-5, 1982, Charlottesville, Virginia.

Rodgers, B. L., and Gunderson, J. R. Development of a set of international standards proposals (ICAC Standards) (in preparation).

Vanderheiden, G. C. 1983. Non-conversational communication technology needs of individuals with physical handicaps. Rehabilitation World, Vol. 7, No. 2, Summer, 1983, pp. 8-12.

Vanderheiden, G. C. 1982. Computers can play a dual role for disabled individuals. BYTE, Volume 7, Number 9, September 1982, pp. 136-162.



MINIBUS ARCHITECTURE FOR INCREASED FUNCTION AND LONGEVITY OF COMMUNICATION AND CONTROL AIDS

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One of the fastest growing areas in rehabilitation at the present time is that of special communication and control systems for physically and sensorily handicapped individuals. It is estimated that in the next five years between 15 and 30 million dollars will be spent on communication and control aids to facilitate the education, daily living, and employment of handicapped individuals. This cost, however, is more a function of the high cost of the separate appliances than it is the number of appliances which are placed. Two major ingredients of this high cost expense are the initial development compared to the total market size, and the relatively short lifetime of the aids as a result of technological advancements.

Proposed is a new approach to communication aid design. This approach would be based on the use of independent and compatible function units, connected by a simple bus. Such a design would allow

a) reduction in cost by allowing custom input modules to be used with third and fourth generation processing and output modules, thus extending the useful life of these specially designed interfaces and providing a longer amortization/profit period.

b) reduction of cost by allowing increased use of existing display, CPU, memory, and special function modules produced for mass market.

c) increase in the ability of aids to be custom configured to meet specific needs of handicapped individuals.

d) reduction in the cost of aids by reducing the number of different aids which must be produced, due to the flexible configurations made possible by using this modular technique.

The approach holds promise for increasing the function and utility of devices for handicapped individuals and decreasing the cost to third-party payers. However, it also poses complex system design questions, and may result in cost increases due to separate component packaging, additional circuitry, and the potential problems encountered with data throughput in systems requiring high information exchange between component parts.

Major Bus Structures to Be Explored

Three basic structures for the distribution of information between modules have been identified so far. These are:

1) the loop
2) the star
3) the tree

The LOOP approach can take the form of either a closed look (such as the HP1L) or an open loop daisy chain approach (similar to the ATARI and some other microcomputer systems). This approach allows the modules to be grouped in any number of packages with at most two connecting wires for information transfer. Closed loop systems will always have two wires; open daisy chain systems would have only one wire if the item were at the end of a chain. Both systems allow for the introduction of additional modules at any point in the system.

The STAR approach can allow for more direct control of the various modules. With this approach, a separate data bus or cable is used between the central controller and each of the other modules. This approach allows for the incorporation of non-intelligent peripherals or modules much more easily than the LOOP or DAISY-CHAIN. In addition, the buses or signal cables between the modules can be tailored to the needs of that module.

The TREE structure is a hybrid of the STAR and DAISYCHAIN approaches. With this approach, information is sent down a trunk which can branch at any point in the chain. This approach does not allow the positive communication which is possible with a closed loop system (such as the HP1L). It does, hoewever, allow the daisychain advantage which provides for a minimum number of connecting cables between packages containing multiple modules.

Significance

The approach could lead to the development of more flexible aids, and compatibility between aids and sub-components of different firms. The latter result would enable smaller firms or rehabilitation programs to develop and market specialized components to meet specific need.

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USE OF TRANSPARENT INPUT AND FEEDBACK MODIFICATION TO ALLOW ACCESS TO STANDARD EDUCATIONAL AND VOCATIONAL SOFTWARE

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The advent of microcomputers has provided the rehabilitation community with a new and very powerful set of tools. Already a large number of special interface control programs is appearing. In some cases, as little as the movement of an eye or erratic pointing motions with the head are sufficient to allow the individual to spell out messages on the microcomputer. Whereas these programs are providing severely physically handicapped individuals with a means to accomplish certain functions (such as writing and environmental control), most of these programs cannot be used in conjunction with already existing software. The individuals are unable to use the microcomputer for the same functions and with the same programs as their non-handicapped counterparts. This is a very serious situation from two standpoints. First, there is a large amount of existing software which could be utilized effectively to meet the needs of handicapped individuals. If they are unable to use the standard software in an unmodified form, its potential benefit will be untapped.

Second, and more important, the use of computers and microcomputers in the life, education, and employment of (non-handicapped) people in general is making access to these microcomputers and their standard software as important as communication and writing. If compatible access is not provided, the advent of the microcomputer could represent just another barrier to the handicapped individual rather than an asset.

Examination of the Problem

The basic problem is that most software for microcomputers is written with the assumption that it is the only program being run on the microcomputer at any point in time. As a result, it is usually not possible to run the special interface program for the handicapped individual in the computer at the same time as one is running the instructional program, the text editor, the game, the accounting package, etc.

The Concept of "Transparency"

In order for individuals to be able to fully utilize microcomputers, it is necessary that the specific hardware or software interface programs be designed in such a way that it is not possible for the computer or the standard program to tell that the interface programs are in place. If an interface or feedback approach is written in such a manner that software programs (no matter how they are written) cannot tell that the modifications are in place or in use, the modifications are said to be "transparent".

While 90-95% of all special interface programs and accessories designed to allow access to computers by handicapped individuals are not transparent, there is a growing number of modifications and accessories which do have varying degrees of transparency.

Semi-Transparent Approaches

The first to appear were a number of software approaches which sought to intercept signals being read from the keyboard or sent to the CRT screen. These approaches generally involved some machine language routines which were "hidden" in some infrequently used portion of memory. The special input routines by Paul Schwedja and the voice output screen for the blind by Peter Maggs are examples of these techniques. These techniques will work with some but not all software. Many more advanced routines assume that all of the memory space is available, and automatically expand their buffer space, erasing any routines loaded into the memory space.

Transparent Routines Which Use CPU

The next category of strategies involves modifications which are fully transparent, but steal time from the central processor during their use. These programs generally inject input directly into the keyboard connector on the CPU and will therefore operate with almost all software which use the keyboard for input. Since these routines are truly transparent, they do not use any of the central memory of the computer (except perhaps tempora its original form). The only software which will not run with these modifications is software which is time-dependent, because these will run more slowly whenever these systems are active. Paul Schwedja's (Seattle) adaptive firmware card is an example in this category.

Fully Transparent Modifications

The final category is that of fully transparent modifications. These modifications generally involve hardware additions to the microcomputer. For input, they usually involve some type of keyboard emulator which accepts input from another aid, another computer, or a special input control routine. A completely transparent auditory CRT display for the blind would have access to the screen display information, but would have a completely independent processor and voice synthesis program which would allow the blind individual to "move around" on the screen and play back the contents at any desired point. Fully transparent adaptations will work with any software. The Trace Keyboard Emulators and Johns Hopkins Morse Input Card are examples of fully transparent modifications.

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THE TALKING BLISSAPPLE: A USER PROGRAMMABLE PICTOGRAPHIC COMMUNICATION/ WRITING PROGRAM FOR SEVERELY HANDICAPPED INDIVIDUALS

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Discussion: Without effective communication and language skills, meaningful education is impossible. For this reason, special communication and language learning systems have had to be developed for non-vocal severely physically handicapped children. For younger children or for mentally retarded children, these systems usually take the form of some type of pictographic system. These systems, although easy to learn, are by their nature very difficult to incorporate into any self-practice or computer aided learning programs.

One very popular and effective approach is the use of Blissymbols. These symbols are both pictographic and ideographic. The effort needed to compress the approximately 1,500-plus vocabulary into a small, fast-running package was, however, beyond the means of any single center. A number of centers therefore pooled their resources to develop an aid which is capable of both displaying and printing Blissymbol messages for their children.

Description: The BLISSAPPLE is a software program contained on a single disk, intended for use with any standard Apple II computer (Apple II or Apple II Plus) with 48K of memory and one disk drive. The BLISSAPPLE turns the Apple computer into a self-contained talking Blissymbol displaying/ printing aid. It can also be used as a talking Blissymbol display/printer for another communication aid.

The objective in developing the BLISSAPPLE was to provide a means to write with Blissymbols which was:

- low-cost
- easily duplicated
- commonly available
- easily updated
- easy to custom-fit for specific users
- modifiable by the user for specific vocabulary

The program which was developed is trimodal in that it can function as 1) a Blissymbol display/ printer for other aids (even very simple electronic scanners); 2) a communication aid with special input keyboards; or 3) a completely self-contained communication aid using the keyboard, game paddle, or game pushbutton (or other switches) for input.

The vocabulary of the BLISSAPPLE is completely user-determined. A library of over 1,400 pre-programmed symbols is available, which can be specifically selected and put into the user's vocabulary. In addition, Blissymbol creation/ revision commands allow the user to create new Blissymbols or modify existing symbols to meet his specific needs.

Program Information and Availability: The BLISSAPPLE program is written in a language called FORTH. Use of this fast and efficient language, combined with special data compression techniques developed at the Trace Center, allows both the BLISSAPPLE program and a 1,400 symbol vocabulary to fit into the core memory of a 48K Apple computer. (Non-compressed storage of the words and symbols would require the memory of ten Apples for the symbols alone. The compressed storage of the symbols takes only about one-half of one Apple's memory.)

Storing both the program and the BLISSAPPLE vocabulary directly in the Apple is important, since continuous access to the disk drive to retrieve symbols would quickly wear out the disk drive (and the disk), and slow the program down considerably.

The BLISSAPPLE program is compiled from source code which occupies five disks (three for the program source code, and two for the symbol segment source code). Once compiled, the program and library fit on one disk, with room for the user's vocabulary as well.

Equipment Required: The basic BLISSAPPLE system is composed of:

- Apple II or Apple II Plus, with 48K of memory
- Disk drive (3.2 or 3.3)
- TV display (black and white)

Optional items for the BLISSAPPLE include:

- Vodex speech synthesizer (for speech output)
- Silentype printer (for printed output)
- Joystick, paddle, or switch (for built-in scanning and one-dimension joystick modes)
- AIO serial/parallel interface card (only needed if BLISSAPPLE is to be used as an output display/printer for another communication aid)

Dissemination of the resulting instructional programs has been initiated through the clinical Blissymbol dissemination centers participating in this cooperative project, the national Blissymbol distributor, and through the Trace Center.

Funding: The development of this software was made possible through a consortium of funding efforts, including (in alphabetical order) Apple Computer Corporation, Cupertino, California; Blissymbolics Communication Institute, Toronto, Canada; Cerebral Palsy, Inc., Green Bay, Wisconsin; David P. Kelso, Madison, Wisconsin; Ted Perry, the Kydetyme Project, San Juan, California; San Luis Valley BOCES, Alamosa, Colorado; Trace Research and Development Center, Madison, Wisonsin; and Gregg C. Vanderheiden, Madison, Wisconsin

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A DATA-BASED APPROACH TO CHARACTER/SYLLABLE/WORD SETS

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One of the principal methods of accelerating a non-speaking individual's rate of communication is to eliminate the need for the individual to spell out words letter by letter. Originally, this was done by including words and phrases along with the alphabet on communication boards. In addition, endings such as "-ed" and "-ing" were often included. Choice of a particular set of words for the communication board, however, was usually done based upon little or no hard data, and often did not represent the optimal set based upon the person's actual usage.

More recently, studies such as that done by Cheryl Goodenough-Trepagnier[1] have taken a more quantitative look at wordsets to try to optimize them. The WRITE system, for example, is a carefully selected set of letters, groups of letters, and words which has been optimized based upon existing word frequency studies. Several versions of WRITE are available depending upon the number of squares to which the client is able to point. These studies, however, are limited to a single level, direct selection communication aid. Adding levels to the system, using a scanning technique, using an encoding technique, or employing any other strategies which make selection of some items easier than others, would result in an entirely different character/unit/word/phrase (CUWP) set. In addition, changing the word usage study used as the basis for the analysis will change the CUWP set. Since the word frequency pattern for physically handicapped individuals is likely to differ from that of non-handicapped individuals, some systematic means for recalculating the optimal CUWP set needs to be generated.

Character/Unit/Word/Phrase (CUWP) Analysis Program

In order to provide a mechanism for analysis of the effect of different word usage patterns and selection algorithms on the optimum CUWP set, a series of programs has been developed and implemented on an IBM Personal Computer. These programs allow the researcher to simulate any selection algorithm, and to determine the optimum CUWP set and physical configuration of vocabulary items on the communication aid being modeled. The programs then automatically calculate an efficiency score showing the increase in communication rate which would be achieved using this set over straight spelling.

The programs allow the user to rearrange the items, change the words, or in any way desired modify the CUWP set and its arrangement. The computer will then recalculate the efficiency, and present the efficiency score of this new system both as it compares to spelling, and as it compares to the original computer optimized wordset and arrangement. In the same manner, the programs allow any arbitrary vocabulary and arrangement to be tested on any communication aid model. They will provide both an overall efficiency score and a comparison of said vocabulary against the computer optimized vocabulary for that aid.

Clinical Use

Although the programs are designed to make modeling of the aids and vocabulary systems possible, they will generally be too detailed to be easily clinically applicable. Major techniques and aids will therefore be pre-modeled and vocabularies analyzed for them. These example vocabularies can be used as starting points in generating custom vocabularies without needing to go through extensive calculation or effort. Emphasis will be placed upon practical discussions of how to use the information provided, and not just upon presentation of pages of data, with little insight as to how it can be used clinically. The manual will be set up in such a way that:

1) clinicians will be able to see the general form and content of optimized vocabulary sets for these aids
2) clinicians will be able to see the effect of various aid parameters on the overall efficiency of wordsets and arrangements
3) clinicians will be provided with rules-of-thumb in vocabulary selection and layout
4) clinicians will be able to judge the direct impact of adding or deleting specific words from an individual's vocabulary and will be able to determine the relative efficiency of the word when placed in different locations or different levels in the system.

The overall effect will be the provision both on a research and on a clinical level of systematic methods for selection and analysis of the efficacy of specific CUWP sets, allowing the user to tap the results in both simple and advanced forms.

Funding: National Institute for Handicapped Research

References:

1. Goodenough-Trepagnier, C., Goldenberg, E.P., and Fried-Oken, M. "Nonvocal Communication System with Unlimited Vocabulary Using Apple and Speec-Syllables. Proceedings of the Fourth Annual Conference on Rehabilitation Engineering, 1981.

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A STANDARD INTERCONNECTION FORMAT FOR ELECTRONIC ASSISTIVE DEVICES FOR HANDICAPPED INDIVIDUALS

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Within the last few years, in response to advancing technology and an increasing attention on rehabilitation of severely handicapped individuals, there has been a very rapid increase in electronic communication and control aids for individuals having severe and multiple physical disabilities. A large variety of different aids, interfaces, and accessories have been developed to meet the very diverse needs, capabilities, and disablities of the different handicapped individuals. As might be expected, nearly every researcher or manufacturer chose a slightly different connector, pin-out, voltage convention, or format for their aids, interfaces, and accessories. The result has been a situation in which clinicians, handicapped individuals, and rehabilitation personnel have an almost impossible task of finding compatible interfaces, aids, and accessories. Since providing a severely and multiply handicapped individual with an effective communication or control system usually involves careful selection and matching of those interfaces which best meet his/her physical abilities with aids which perform the functions that he/she needs with accessories compatible with his/her age, cognitive abilities and activities, the additional restrictions due to the incompatability of different systems has created severe (and unnecessary) problems. The end result is often that the handicapped individual is fitted with an aid, interface, and accessories which do not really meet his/her needs well, because the pieces he/she really needs will not work with each other.

The Common Interconnection Format project has developed, through national and international cooperation, a common format which when followed allows for the easy identification of interfaces and aids which can work together, and in fact ensures that such aids can be hooked together by non-technical personnel. This standard is three-fold, involving:

1) a set of three common connectors (2-, 9-, and 5-pin)
2) a common technical format for aids and interfaces
3) a simple, straightforward naming format (or code) which will enable non-technical people to mix and match aids, interfaces and accessories which are electronically and mechanically compatible in order to meet the specific needs of the handicapped individual.

Some of the constraints which the standard accomodates are:

1) The format is compatible with aids, interfaces, and accessories already in production or in the field.

   It allows for adaptors to enable interconnection of pre-format aids, and resolves power supply conflicts.

2) The format provides a simple, straightforward naming format to enable parents/teachers/rehabilitation personnel to easily identify and match compatible aids, interfaces, and accessories.

3) The connectors which have been chosen are simple, and are convenient for users; they are a consumer type connector, rather than a commercial or engineering type.

4) The format and connector are convenient to manufacturers, and are cost-effective.

5) The format has identified common, convenient, and effective approaches to interface development, and encourages their use in order to reduce the variety and complexity which currently exists.

6) The format is an open or living format which allows for innovation and future development while maintainint the simplicity and compatibility of the system.

7) The format is compatible with other existing standard formats which apply to such aids and interfaces.

8) The format is able to handle the extremely wide variety of interfaces for the handicapped; it can handle the wide variety of switch arrays available, which may be from 1 to 64 switches, in any of a dozen configurations. It also allows for analog, digital (serial and parallel) and resistive/reactive transducer output signals.

9) The format provides for only three interface connectors, thus ensuring that input transducers/user interfaces which are electronically and functionally compatible with an aid are also mechanically compatible.

10) The format provides maximum flexibility to allow for newer electronic interfaces and "smart" interfaces now being developed.

11) The format allows for multi-input aids which must be able to accept a wide variety of different interfaces (to meet the needs of different users) on a single connector.

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DUAL AND NESTED COMPUTER APPROACH TO VOCATIONAL AND EDUCATIONAL COMPUTER SYSTEMS

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Computers are making rapid inroads into both the educational and work environments. As they do, they are beginning to reduce the amount of paper and physical manipulation required in favor of information manipulation. For physically handicapped individuals, this can represent a significant decrease in the impact of their handicap. Activities that would formerly require extensive physical manipulation of documents and writing instruments can all be carried out electronically.

In order to take advantage of this capability, however, the handicapped individual must be provided with a mechanism which will allow him/her to issue commands at a meaningful and productive rate. Many physically handicapped individuals are unable to effectively use a keyboard. Other individuals can use the keyboard, but their rate of input is four to ten times slower than even a slow normal typist. As a result, they would only be able to complete a day's work every ten days, or a night's homework every week or two. For these individuals, some type of alternate input modes and acceleration techniques are required if they are to be able to meaningfully access and use the microcomputers as aids to their education or employment.

Two Approaches to Computer Access: The traditional approach to providing access to computers has been to develop special software to either provide an alternate input other than the keyboard or to provide acceleration routines such as abbreviation expansion to increase the person's effective input rate. Since these routines will rarely coexist with standard, unmodified software, desired function routines (e.g., text editors, accounting packages, etc.) had to be custom written or specially adapted to work with the input routines. Although this approach works for very simple applications or demonstrations, it is generally not functional in real-life applications.

In many cases, the best packages are sealed in such a way that they cannot be entered, and source code is not available. In addition, new and better software packages are continually becoming available. To limit handicapped individuals to only those few (and older) programs which have been adapted would be a serious handicap in itself.

A Dual Nested Computer Approach: In order to overcome this problem, Trace Center has adopted a dual nested computer approach in the design of its vocational microcomputer systems. Although this was not the approach originally taken by the Center, it soon proved to be not only the most flexible, but also the least expensive approach to developing custom microcomputer systems.

With the dual nested approach, one computer is used to handle special interface and communication acceleration programs. The output of this computer is then fed into a second microcomputer through a keyboard emulator (or into a large computer through its normal terminal ports). Because the second computer is completely unburdened of any special input or acceleration adaptations, it is able to run at full speed, and use standard unmodified software. Because the first computer does not have to support the function software, the full resources of the computer are available to the handicapped individual to implement his special input and acceleration routines. As a result, large vocabularies and sophisticated assistance programs can be utilized. This freedom and access to the entire computer allows rehabilitation personnel to utilize more modular software and higher level languages. The result is a much lower cost to configure the system for the individual, and much higher performance.

Non-Matched Computers: Because the two computers are completely independent, it is also unnecessary to have both computers be the same model, make, size, or configuration. The second computer can be of whatever size and configuration is necessary to run the type of applications that the individual needs. By using a universal keyboard emulator, the computers presently on-site in the school or on the job site can be used running the same software programs used by the other students or employees. In this fashion, the handicapped individual's computer (the first computer) could be simply regarded as a "super keyboard".

Moreover, since the first computer will not be running standard software, it does not have to be either a standard computer or computer configuration. In many cases, a lower cost system can be used for this computer. In one application, an Atari 400 ($359) computer is being configured as the first computer, and interfaced to a $2,500 Apple II computer system which runs the individual's application programs. In this case, the first computer is less expensive than many of the plug-in modules for the second computer, and less expensive even than some of the software programs run on the second computer.

Conclusions: Where special software is required in order to enable an individual to access a computer system, it is often less expensive and more functional to actually use two microcomputers than to try to implement all of the functions within a single computer. This is especially true where standard software systems or existing software packages are used, as would be true in educational and vocational applications. In many cases, the second computer can be the computer or computers already on-site and being used by the non-handicapped persons, enabling the handicapped individual to parallel the educational or employment activities of his colleagues without requiring modification of the standard software systems.

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HYBRID OPTICAL HEADPOINTING TECHNIQUE

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For many severely physically handicapped individuals, the use of a head or mouthstick has proven to be an effective mechanism for pointing or operating typewriter keyboards. More recently, the lightbeam headpointer has been introduced.[1,2] results with the lightbeam headpointers showed that they not only were easier to use for many headstick pointers, but that they could also be used by a large number of clients who were previously unable to use headpointing at all. Many individuals who were able to point with their hands were also found to be much faster and more accurate pointers using the lightbeam headpointer.

Because of this increase in communication speed and accuracy, as well as the accompanying improvement in body tone and positioning noted for many individuals, the lightbeam headpointer is quickly becoming a major technique for communication. Unlike the headstick, however, it cannot be directly used to manipulate objects or activate keyboards. To overcome this problem, several research teams developed lightspot sensitive selection panels; these include the PILOT from England, the LOT from Holland, and the OCCUR from Canada[3]. Because of the high power of the lightbeam required, and the expense for the circuitry associated with each of the analog sensors, all of these systems were very expensive and received relatively little clinical application.

An Alternate Approach: An alternate approach to sensing headpointing was developed at the Rehabilitation Engineering Center in Memphis[4]. This technique used a matrix of discrete LEDs and a tunnel vision sensor attached to the user's head. As the individual pointed, the LEDs nearest to the target center on the display board would light. This approach provided a low-cost and fairly ambient light insensitive technique for detecting head pointing, and was quickly picked up and made commercially available by Prentke Romich in their ProScan, Express I, and Express III communication aids.

Although this provided a low-cost headpointing technique, it offered only discrete feedback to the user as to his current head position. As he moved off of the desired target, there was no feedback until the LED suddenly jumped to the next character position. The individual then had to try to compensate for his error, causing the LED to jump back and the countdown to square selection to reset to zero and begin anew. It was found that only about 2 out of 10 individuals who could use the lightbeam (which provides continuous head position feedback) for pointing were able to use the reverse optical headstick (with discrete feedback). Consequently, its application was limited to a small percentage of potential headpointers.

The Hybrid Optical Headpointer: To combine the best features of both approaches, a hybrid technique was tried at the Trace Center and the Communication Aids and Systems Clinic at the University of Wisconsin. This combined a continuous lightbeam with the Memphis Optical Headstick. The result was a system which was highly immune to ambient light and provided continuous head position feedback. In addition, the discrete LEDs gave an added measure of feedback, confirming the aid's interpretation of the target. Using this hybrid technique, the user sees a spot of light which he directs around the selection panel. When he is trying to point to a square, he simply tries to hold the spot of light (which is usually constantly moving due to the client's erratic motions) so that its motions are centered over the desired square. As his headpointing deviates in any direction from the target center, he can see this deviation and move to correct it before he leaves the target area. At the same time, the user will observe the LED in the center of the target area, which will remain lit as long as his excursions stay within allowable bounds. If he momentarily leaves the allowable bounds, he will be able to easily detect this, since the LED will flick to a neighboring square and back again. This additional feedback can be very important, since hysteresis can be built into the system to allow an individual to have stray motions which actually leave the target square by small amounts but which are not counted as being "off target".

Clinical Results and Preliminary Conclusions: Results to date have found that none of the individuals who have been able to use a lightbeam headpointer have been unable to use the hybrid approach (using the same size selection squares). In addition, individuals who were able to use the optical headstick without the lightbeam reported that the combination (hybrid) was less strenous. Their rate and accuracy for selections also increased. More extensive studies are planned.

References:

1. Levy, R., and Waksvik, K., "The Design and Evaluation of an Optical Headpointer". Proc 5th Conf on Syst and Dev for Disabled, 1978.
2. Frameworks, Inc., Route 1, Box 56, Cedar Grove, NC 27231; Jim's Instrument Supply, P.O. Box 5157, Coralville, IA 52241.
3. Vanderheiden, G., and Grilley, K., eds., NonVocal Techniques and Aids for the Severely Physically Handicapped, University Park Press, Baltimore, Maryland, 1975.
4. Hodgetts, M.S., Beard, R.J., and Hobson, D.A., "Electronic Device Control Using the Retro-Reflective Concept". Proc Int Conf on Rehab Eng, 1980.

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DESIGN OF UNIVERSAL KEYBOARD EMULATORS

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Individual modification of software systems to fit the needs of handicapped individuals is both makeshift and expensive, and is therefore of limited value. In addition, the technology of computer/information systems is growing at a tremendous rate, and software programs are therefore continually changing and evolving. Handicapped individuals cannot keep up if they must rely on only those systems and software versions which have been adapted for their use. Techniques must therefore be developed which allow a handicapped individual using a nonstandard input device to use standard software. Since most software is designed to use input from the keyboard, a device which precisely emulates the keyboard will be transparent to all software. To this end, the Trace Center is designing keyboard emulator(s) that will work with a variety of personal computers (and terminals*).

The major goals in our design are:

1) that the keyboard emulator mimic the actual keyboard so well that it is invisible to the system

2) that the keyboard emulator allow the actual keyboard to be used normally with the keyboard emulator installed

3) that the keyboard emulator accept input via standard serial data

4) that the keyboard emulator work with as many of the most popular personal computers as possible

5) that the keyboard emulator be affordable.

In order for the keyboard emulator to be invisible to the computer, it must exactly duplicate all of the normal responses of the keyboard, including any control line signals. To make the keyboard emulator as universal as possible, we have analyzed the keyboards of several computers, including the Atari 400 and 800, VIC, Pet, CPM, Apple II and III, Xerox, TRS-80 II, III, and Color, and the IBM Personal Computer. We found three main types of keyboards:

1) keyboards that output serial ASCII coded data

2) keyboards that output parallel ASCII coded data

3) keyboards that use the central processor to read the keyboard matrix directly.

The most demanding type of keyboard to emulate is the third type. The TRS-80 Model I is an example of a keyboard matrix type machine, where the CPU treats the keyboard as memory and directly reads the keys as bits. On the TRS-80, the keys are switches arrayed in an 8x8 matrix so that each key potentially connects one column to one row. In order to determine which key has been pressed, the computer addresses one row at a time, and examines the eight columns as an eight-bit byte of memory.

The reason that this type of keyboard is difficult to emulate is that the polling of rows is done very quickly (in the time of a single normal memory fetch). This leaves very little time for the keyboard emulator to put its simulated column signal on the bus when it determines that the CPU is polling the proper row. As a result, it is difficult to use a microprocessor-based keyboard emulator, since the microprocessor in the emulator cannot respond directly to the row polling strobes quickly enough. Therefore, it becomes necessary to use a more complicated strategy that can respond very quickly to the row polling strobes.

Two approaches can be used to handle this rapid access. The first is to load a block of RAM with the bit pattern corresponding to a single depressed key. The CPU would then read this block of RAM in the same fashion as it reads the keyboard. This approach requires bus separator circuitry in addition to the RAM block and the microprocessor.

The second approach uses a gate array or crosspoint switch array which is controlled by the microprocessor. To simulate a key closure, the gate array is enabled in such a way that a direct logical path is created beteeen the desired row and column.

In use, the keyboard emulator is plugs into the personal computer between the keyboard and the main CPU board. The handicapped person who desires to use the computer simply plugs his/her intelligent communication aid into the emulator. He/she then has control of the computer through the communication aid and is free to use the computer to run any standard software programs, and, because of the design of the emulator, the normal keyboard also continues to function in the normal manner.

* The keyboard emulator will work with some terminals, but a simple solution is to use a "data stream routing module" that connects the communication aid to the line between the terminal and the computer. This device is also being developed at the Trace Center.

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TEN-BRANCH ABBREVIATION EXPANSION FOR GREATER EFFICIENCY IN AUGMENTTIVE COMMUNICATION SYSTEMS

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At the present time, one of the primary barriers to the effective use of augmentative communication systems is the rate of information transfer. Whereas normal speech rates are about 200 words per minute, and normal writing rates are about 35-40 words per minute, the usual rate of character input by physically handicapped individuals is .5 to 3.0 words per minute. Because of this, a number of specific approaches have been developed to try to accelerate the rate at which an individual can feed information to a writing system in order to increase his effective rate.

Most acceleration techniques involve the use of full word or phrases to supplement spelling. For the individual who can point to a large number of squares (or keys) (approximately 200-300), the words or phrases can be directly displayed. Levels can be used to allow more than one word or phrase per square (or key). Both of these techniques, however, have limitations in the size of the vocabulary which can be supported (usually 1,000 words or less). When one considers that the normal five year old child operates with a vocabulary of 2,500 words, and the adult with a vocabulary of 10,000 words, the extent of this limitation can easily be seen. It is also difficult to display longer phrases or sentences which cannot be written on a portion of the square (or key).

One solution that has been tried is the use of number codes to access the vocabulary items. For smaller vocabularies, this is a powerful and useful technique. As the vocabulary gets larger, however, it gets increasingly difficult for the individual to remember the number code for each of the words.

Abbreviation Expansion: In an effort to circumvent the problems associated with memorizing number codes, researchers and clinicians have tried using letter codes or abbreviations for words. This technique has the advantage that letter sequences which have an orthographic or phonetic relationship to the desired word can be used, making memorization of the codes easier.

In some cases, abbreviations are selected on an idiosyncratic basis; in others, they are made up in some systematic fashion, using a set of rules. With the latter approach, an individual would generate the same abbreviation for the same word over multiple trials. If this approach is taken, one would not need to remember the abbreviation for each word explicitly, since it is easy to reconstruct (for this method, it is beneficial to have some type of display of the word which has been indicated before entering it into the text in order to check accuracy of recall.

A Means for Implementing Abbreviation Expansion Routines: Initial abbreviation expansion routines looked for strings of characters followed by a period. Whenever this occurred, the aid would look up that string in the dictionary to see if it was an abbreviation on record. If it was, the aid removed the abbreviation and replaced it with the proper word or phrase. This approach could result in problems, however, if letter/period combinations were used in text and at the end of sentences.

Use of a special terminator, rather than a period, solves this problem. Whenever the expansion program encountered this special terminator, it would look up the character string immediately preceding the terminator. The special terminator might be implemented using a key labeled "EXPAND".

This technique would allow abbreviations of any length to be used. As a result, it is possible to have 26 two-keystroke 676 three-keystroke and 17,576 four-keystroke abbreviations (remembering that it takes a keystroke to hit the terminator or EXPAND key). Many of these keystroke combinations, however, do not yield useful letter sequences (in terms of mnemonic characteristics) and would generally not be used. Also, it is generally not very effective to use four-keystroke sequences to encode five-letter words. Finally, many of the codes (such as those starting with the letter "S") are used up quickly, while others (such as those starting with the letter "Q") would go unused.

TenBranch Abbreviation Expansion Approach: In the above abbreviation expansion routines, it can be noted that one keystroke is required at the end of every abbreviation expansion routine, in order to activate the look-up system. With the ten-branch abbreviation expansion routine, any sequence of alphanumeric characters which ends with a number (e.g., "A1", "TH3", "5") is taken to be an abbreviation. This results in 10 1key, 260 2key, 6760 3key, and 17,560 4key codes.)

If all words were used with equal frequency, with a 10,000 word vocabulary, this approach results in an additional increase in efficiency of approximately 25%. Since the frequency with which words are used is very non-linear, the increase in efficiency is considerably larger. (Computations to determine the exact efficiency difference require the simulation of the different techniques, and the use of a complex program; these computations were still underway at the time of publication for this abstract.)

This technique can be easily implemented on a standard keyboard without the addition of extra keys, legends, etc. This implementation provides for completely user definable abbreviation vocabularies. In addition, it provides constant cuing to the user of the abbreviations as s/he is typing in order to facilitate his/her memory.

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THE EFFECT OF INCREASED SENSOR AREA ON INPUT RATE AND ACCURACY OF THE EXPRESS III COMMUNICATION AID

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ABSTRACT

By enlarging the effective sensing area of an EXPRESS III handpiece, the input rate of some users increased by as much as 1.6 times of the rate using the standard handpiece. The large sensor allowed for placement of the handpiece anywhere within a square to select the square. It also had a hystoresis effect which helped to increase the accuracy and thus the rate for spastic individuals.

BACKGROUND

The EXPRESS III system, made by the Prentke Romich Company, has several input modes. One of these is a direct selection technique where an individual selects squares by pointing to the LED in the corner of the square with a hand-held sensor. The EXPRESS III uses an orthoganal array of LEDs (light emitting diodes) which sequentially flash on and off. Each LED is in the center of a 1" square, and emits light through a 3/8" diameter clear window. The sensor (a photo diode) senses the light from an LED in the same manner as a lightpen works on a TV screen to determine the square being selected by the user. If the LED remains sensed and lit for a set period of time (which is user adjustable), that square is selected. In order to make another selection, the sensor must first lose the signal from the original LED, and then sense another LED, even if the same square is going to be reselected.

PROBLEM BEING ADDRESSED

Clinical evidence shows that the sensor on the EXPRESS III can be too small for effective use by some individuals. The small size of the sensor reduces the speed at which a person may select a square, since the handpiece must be placed very accurately. For a person who has very slow fine motor control, or who is spastic, this can be very frustrating. If the user places the sensor very close to the LED target, but not on top of it, the selection will not register until the sensor is moved the very small distance to bring it directly over the LED. For some individuals, moving the sensor a small distance, and keeping it there, is very difficult, if not impossible. What usually happens is that they overshoot and select another square. One solution to this problem would be to enlarge the LED target. It is impractical, however, to increase the LED size for all of the LEDs. The most logical solution was to enlarge the effective area of the sensor.

MATERIALS AND METHODS

The effective area of the sensor was increased by taking the sensor and mounting it in a black tube, with an inside diameter of 0.75", about 0.75" above the bottom of the tube. The tube had a protective clear plate set at the bottom. The sensor was mounted to another clear plate at the top using a microminiature phono jack. This allowed the center of the sensor to be anywhere within a 1 1/8" diameter area around the LED. This arrangement is shown in a corss-sectional view of the enlarged sensor (Figure 1).

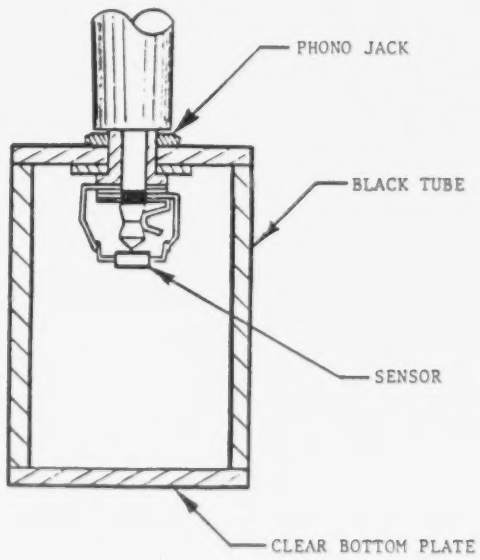

Figure 1

PRELIMINARY TESTING

Three subjects and one control were used to test this new design. All were in wheelchairs. Subject 1 had mild cerebral palsy; Subject 2 had moderate to severe athetoid-ataxic cerebral palsy; and Subject 3 had moderate to severe spastic cerebral palsy. Subject 4 was a non-handicapped control subject. The subjects were asked to select 8 squares in a specified order, and to do this twice in a row, so that a total of 16 squares were selected for each test run. After several preliminary runs, each subject was asked to repeat the test run three times. The raw results, of the time to complete a run and the number of wrong selections, were recorded. The preliminary runs were used to allow the subjects to become familiar with the required selection sequence, and to be near the top of their learning curve. The results of the test are shown in Table 1.

Subjects 1 and 3 increased their output rate by 63% and 37% respectively. Subject 2 showed a decrease in speed of 13%. The control subject showed an increase of only 7%.

DISCUSSION

Ease of Use

For all of the subjects, the physical ease in using the large sensor and the small sensor were about the same. The subjects expressed no difference between the two, and no visual evidence was present to show that using one sensor produced more physical stress than the other. However, the prototype was physically larger and made of an opaque material. This larger sensor obstructed the user's view of the squares more than the small sensor. All of the subjects complained that it was more difficult to tell exactly where they were pointing when using the large sensor. Even with this problem, however, Subjects 1, 3, and 4 said they felt it was mentally easier to use the larger sensor.

Speed

The increase in speed is a result of the larger sensing area. The subjects did not have to be as accurate with their pointing in order to select a square. There was greater improvement for the subjects who had more difficulty with small corrective movements. For the normal subject who had accurate pointing and good small motion control, the advantage of the large sensor was not as great for speed, but was still advantageous for ease of use.

Accuracy

There appears to be no difference in accuracy between the two sensors. However, for Subject 2, there was much difficulty in knowing where the center of the sensor was pointing when using the larger sensor. This was accentuated due to the fact that this subject used the EXPRESS III in a high position, where the angle of sight was quite low.

Height Selection

The sensor became active during the downward motion at 1.2", and inactive on the upward motion at 1.7", nominally. The height of the sensor above the surface was chosen to be 0.75" since it was desired that the sensor be active when placed on the surface but inactive when over an inch above the surface. The height and inside diameter combination made the largest effective diameter of the sensor roughly 2.3" at its maximum distance from the surface. This was larger than desirable. A better design would have a constant effective diameter at all heights. After making the modification, it was discovered that the increased admittance of light made the sensor active at 2.5" but inactive at 3.5". However, this did not seem to pose significant problems with the design since the subjects kept the sensor flush with the surface during use, and lifted it infrequently.

Subject #	Small (spm)	Errors %	Large (spm)	Errors %	Increase (X)
1	27.7	0.0	45.1	1.9	1.63
2	25.4	2.8	22.0	10.8	0.87
3	30.9	3.1	42.3	0.0	1.37
4	64.0	0.0	68.6	0.0	1.07

spm = selections per minute
% = # wrong selections / total # of selections
X = spm of large sensor / spm of small sensor

Table 1

Diameter Selection

The diameter of 0.75" was selected based on the distance between the effective area of the LEDs. The minimum distance between the effective area of two LEDs is 0.625". To produce a hysteresis effect when moving back and forth between neighboring LEDs, the effective diameter of the sensor needed to be greater than this minimum distance. By choosing the diameter of the tube as 0.75", the center of the sensor has to be more than 0.56" away from the center of the square before being able to select a neighboring square. To reselect the same square again, the sensor has to be less than 0.44" away. There is, therefore, a hysteresis of 0.12" on the radius.

CONCLUSION

It is apparent that for some users, a larger effective sensor area would greatly increase the ease and speed of input without any loss (and in some cases an increase) in accuracy. The modification to the original design is minor, and would not significantly increase the cost. Another version of the sensor will be made to try to solve the problem of visibility and non-uniform effective sensing diameter. The results of this second version will be reported later. Once an acceptable design is reached, it will be passed on to the Prentke Romich Company.

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ALTERNATE ACCESS TO ALL STANDARD COMPUTERS FOR DISABLED AND NON-DISABLED USERS

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Abstract

Many advances are being made to allow disabled individuals to access computers. Specialized interfaces that can be operated with voice, sip-and-puff, and even the eyes have been developed. For blind individuals, special output forms using braille and voice have been developed. Unfortunately, most of these adaptations could originally be used only with specialized or selected software packages. An "alternate access" approach is now being developed which would allow disabled individuals to access all standard software programs as well as the specialized software. In addition, these "alternate access" techniques promise to benefit non-disabled users as well.

The Triple Roles

In examining these problems, it is important to realize that there are three roles that computers play in the rehabilitation of disabled individuals. The first role is as a therapy device. Therapy for many disabilities, especially those from brain injuries, may be able to take advantage of the low cost and extreme patience of computers to provide individuals with self-paced therapy programs.

A second application of computers is as personal aids to disabled individuals. Here, the computer running special software could act as an individual's "pencil and paper," filing system, translator (translating text into speech or braille), etc. In this role, the computer acts as a personal aid to the individual, and provides functions which other individuals generally achieve in some other fashion. Such a computer is owned by the individual, and can have special programs and modifications made for it.

The third role that computers will play in the lives of disabled individuals is the same role that they will play in the lives of non-disabled individuals. Computers are very quickly being incorporated into our society at all levels, from education to employment to daily living to recreation. These computers generally do not belong to us, but are rather computers which we encounter in the environments of our schools, jobs, etc. It is this third role of the computer that we are concerned about in this paper. Specifically, we are concerned about the severe handicap that a disabled individual will experience in education, employment, and even daily living, if he is not able to freely access and use the many different computers which he is going to be encountering in his daily life. In fact, if access to these different computers cannot be assured, participation by the disabled individual in most regular education and white collar employment settings will become impossible within the near future.

The Solution Strategy

The solution strategy proposed and being explored is to put a generic input/output port on all computers and information systems. This input/output port would accept input from alternate input devices (special keyboards, special aids, etc.) and treat it exactly as if it came from the standard input devices (the keyboard, a mouse, a touchscreen). A similar treatment would also be made for any information being sent out to the standard output display. Here, any information being sent to standard output displays (CRT screens, speakers, printers) would also be present on the alternate output connector, which could be connected to alternate displays (braille displays, voice output, etc.).

Such an approach would not only allow use of the system by disabled individuals, but would also enhance use by non-disabled individuals.

A disabled individual would use the system by simply plugging his own specialized input system(s) into the jack, and proceeding to use the system as would anyone else. A disabled individual would have to secure for himself specialized input/control systems optimized for his residual abilities. These communication aids or interfaces would be kept by the individual as a personal aid. Whenever he encountered an information system he needed to operate, he would simply connect his interface and use it.

Non-disabled users could use the alternate inputs to connect their own specialized inputs for various purposes. Individuals who like to use specialized one-hand keyboards, Dvorak keyboards, abbreviation expansion, or shorthand keyboards, etc., could simply connect them to whichever computers they were using given time. Manufacturers would also be able to make generic "voice input keyboards" which would connect into any company's computer, since the "alternate access" input port would be standardized. The alternate input connector would also facilitate use of the computers in environments where specialty keyboards were required. For example, if a computer was needed in an explosive or hostile environment, a "standard hostile environment keyboard" could

be connected to the computer on this alternate access port.

The alternate output portion of the connector would function in a similar manner. Blind or other sensory-impaired individuals would keep special tactile, vocal, or visual (for the deaf) displays with them, which could be connected to the computers and information systems they encountered in their environments. Any information which was produced in a form that they would not ordinarily be able to perceive could be translated by their personal device into a form usable by them. Again, the non-disabled market could also make use of these output connections to provide generic input to special displays of many types.

Work to Date in this Area

Work on this overall objective is currently proceeding in both the disabled and non-disabled market. In the disabled areas, a small device called the keyboard emulating interface (Vanderheiden, 1981; Korba et al., 1983) has been proposed and developed for a number of popular computers. This module is installed in the computer between the standard keyboard and the rest of the computer. It accepts keystrokes from either the standard keyboard or a special RS232 input and passes them on to the computer as keystrokes. As a result, information fed in through the RS232 port of the emulator is passed on to the computer in precisely the same form as keystrokes from the computer's standard keyboard. The computer cannot tell keystrokes coming from the keyboard from those coming in the serial port. The keyboard emulating interface therefore allows individuals using specialty input devices to use the computer and all of its standard software. Any software which operates off of the keyboard can be used by the disabled individual without modification. This type of modification is termed a "transparent" modification.

Transparent techniques are also being developed for blind and visually impaired individuals. For these individuals, the problem is dealing with the CRT screen. Techniques have been developed which tap into the operating system of the computer and are able to track the information which is written to the screen. This information is then displayed on a special display (voice, braille, or expanded display) usable by the visually disabled person. The system from Visualtek is a good example of a system for individuals with low vision (Vanderheiden et al., 1984). Their aid (which has versions for the Apple, IBM, Radio Shack and other computers) recreates the characters in an enlarged format on a separate display. The size of the characters can be varied, and can be made so large that a single character fills the entire screen. Using a joystick or other interface, the individual can have the text automatically scrolled past at a user-controlled rate. Since the system is completely transparent, and does not interfere with the operation of the standard computer, it can be used with standard off-the-shelf software.

For individuals who do not have residual vision, other systems are available which provide transparent voice output of the content of the computer's screen. Systems such as Blind.talk, for the Echo II or Echo PC, and Total.talk, for the IBM, allow the disabled user to use the standard unmodified software and have the computer read out the contents of the screen at the user's direction.

All of these systems have their limitations, however. None of the computers or operating systems were originally designed to support these types of modifications. As a result, the modifications must be custom designed for each new computer, and each new model of a computer, as they come out. This is costly, and does not allow the user to easily move between brands of computers, taking their special hardware with them. Also, as new operating systems are introduced or updated, additional time must be spent on the part of the manufacturers of the special interfaces to ensure that their modifications will still work, or to revise them so that they will. Provision of a standardized access port to the keyboard handling and display driving routines would greatly simplify the task of these specialty manufacturers, and increase the longevity and applicability of their devices across computers, benefiting both manufacturers and consumers.

Opportunities from Advances and Directions in the Non-Disabled Market

Although such a standardized access system would be beneficial to disabled individuals, it normally would be unrealistic to expect that such a standard access port be adopted or implemented on standard manufacturers' computers. There are, however, a number of developments in the field of microcomputers which are heading precisely in this direction.

A number of operating systems are picking up the concept of a "keyboard object." For example, TopView, the new operating environment from IBM, is capable of running several programs concurrently. Since they are not all connected to the keyboard at the same time, TopView sets up a "keyboard object" for each program. Any characters put into the keyboard object are used by the program as if they came from the standard keyboard. One result of this is that one program can in fact create the "keystrokes" for another program. All of the programs running in the background of TopView receive their input through such a keyboard object. If this can be extended to the foreground program

as well, and an option built into the system to allow it come from an external input port, then the problem of handicapped access to the standard keyboard would essentially be solved (for this case). Since a good case can be made for this for the non-disabled market (to allow use of alternate keyboards, voice input, etc.) as regular computer inputs, the concept becomes feasible. In fact, similar capabilities have been available on mainframe computers for some time.

Similarly, work with virtual display interfaces (VDIs) may provide the capabilities and links to the standard visual display necessary for alternate displays. The purpose of the virtual display interfaces (which again is being developed for the standard computer market) is to allow a program to create a visual image on a screen with unknown resolution; that is, the program can write characters, draw circles, etc., on a screen when it doesn't know exactly how many dots there are, or exactly what the screen configuration is, in advance. Instead of sending the dot information directly to the screen, therefore, the program passes the information to the VDI, which connects to routines that draw/write the information on the screen with the maximum resolution available to that screen. Since an individual may want more than one display connected to a computer (e.g., a built-in screen and a high-resolution projection screen), there may also be need for exporting this VDI information so that it can be sent to the separate projection display. Again, the availability of the video display information in standardized form, on an external connection, could provide the groundwork for the use of alternate displays for disabled individuals.

Pipelining, new windowing capabilities, and the increasing use of multitasking and nesting in the newer computer systems is therefore beginning to provide us with exactly the tools we need (Vanderheiden, 1981) for making computers more accessible to a wider population. Moreover, these developments are occurring within the standard computer field, and for the benefit of the non-disabled population. If these developments are implemented properly, they will go a long way toward assuring alternate access to standard computer systems for individuals with disabilities as well as access for the general population. If, however, they are not implemented properly, we may have the equivalent of a situation where an entire city is paved with nice concrete paths which greatly facilitate the mobility of disabled individuals, but which all have a 6" or 8" curb at the corners.

In order to help explore the needs of disabled individuals, and to be sure that unnecessary (and unneeded) curbs are not put in accidentally, a number of efforts have been started to bring the manufacturers of standard computer hardware and operating systems together with researchers, consumers, and developers of specialized access hardware, to see how the new developments such as those discussed above can be implemented in such a way that they maximize the potential and opportunities for individuals with disabilities. Several projects at the Trace Center are now focused on working with standard hardware manufacturers to facilitate this process. The Office of Special Education and Rehabilitation Services (OSERS) of the Department of Education has also instituted a major initiative in this area, which is being coordinated with the White House Private Sector Initiatives Program. Through these and other cooperative efforts nationwide, there is reason to be optimistic that the type of solution strategy being proposed can and will be realized. The most compelling reason for this optimism is that it is likely that more non-disabled individuals will benefit from it than disabled individuals. As a case in point, curbcuts are used by many, many more non-disabled individuals than disabled individuals.

References

Korba, L.W., Nelson, P.J., and Park, G.C. "Matrix Keyboard Interfacing with the National Research Council's MOD Keyboard." Proceedings of the Sixth Annual Conference on Rehabilitation Engineering. San Diego, 1983.

Vanderheiden, G. "Practical Applications of Microcomputers to Aid the Handicapped." Computer, January 1981.

Vanderheiden, G., Bengston, D., Brady, M., and Walstead, L. International Software/ Hardware Registry (Second edition). Trace Center, 1984.

Work on this project was supported by Grant #G-008300045, from the National Institute of Handicapped Research, DOE.

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A PORTABLE DECTALK SPEECH SYNTHESIZER

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ABSTRACT

A portable version of the high quality DECtalk speech synthesizer has been developed by the Trace Center at the Waisman Center, University of Wisconsin-Madison. The portable DECtalk can use two internal 12 VDC batteries, an external 19 VAC adapter, or an external 24 volt DC power supply. It can be turned on and off either manually or automatically by the user's communication aid via the RS 232 serial communications port.

INTRODUCTION

Speech synthesizers can play a very important role in the education and employment of non-vocal severely handicapped individuals. However, high quality speech synthesizers with unlimited vocabulary have not been available in a portable form. To be of complete use for handicapped people, a speech synthesizer must be easily portable and operate for at least a full day on a single charge.

BACKGROUND

The DECtalk (made by Digital Equipment Corporation) is a commercially available text-to-speech synthesizer which uses advanced speech synthesis algorithms to produce very intelligible speech. It has seven different voices: three men's voices, two women's voices, a child's voice, and a user definable voice. This is an important capability, since many children and women refuse to have a male voice speak for them regardless of how sophisticated and intelligible the synthesized speech sounds.

The DECtalk can be directly connected to a modular phone jack, so the speech can be transmitted over telephone lines without losing its quality. The DECtalk also has a dictionary that can have new words added or have a whole dictionary downloaded from a host computer. It has a very sophisticated algorithm for dealing with numbers, and also has the ability to produce the alternate pronunciation for certain words.

These features make the DECtalk an excellent speech synthesizer for non-vocal individuals, and it was therefore chosen as the speech synthesizer to be made portable.

DESCRIPTION

Design Goals

The overall design goal was to make the DECtalk portable and usable by someone in a manual or electric wheelchair. This meant making it mountable to a wheelchair, resistant to damage from rough use, and resistant to damage from being used in the rain or around areas where accidental liquid spillage might occur. The DECtalk must also be made able to operate for a long time on a single charge, so that it will not be necessary to frequently recharge the unit. The minimum requirement was that the charge should last a full day. For ease in adjusting the volume and adding an external speaker, an external volume control knob and a speaker jack were added to the outside of the package.

Operational Modes

The portable DECtalk operates in two modes: a manual mode and an automatic mode. In the automatic mode, the custom designed power supply automatically turns power on for the DECtalk mother board as soon as the DECtalk receives a character via the RS-232S serial port. It is ready to receive text after another 250 ms, and turns off after a specified time-out. The automatic mode saves battery power by turning the DECtalk on only when text is being spoken and automatically powers down the system after it is finished with the utterance. This increases the length of time the DECtalk can be used before needing to be recharged.

The manual mode operates in exactly the same way as an unmodified DECtalk. It is turned on and off by a switch (i.e., the DECtalk is always on when turned on by the switch). This mode is necessary to allow the portable DECtalk to work with software expecting an unmodified DECtalk.

Automatic Power Down

The power board has two adjustable time-outs, one to turn off the fan and the other to power down the DECtalk mother board. The time-out for the mother board can be varied using jumper pins from 1/2 second to 256 seconds, and the time-out for the fan can be varied from 16 seconds to 256 seconds. In order to prevent possible overheating of the mother board, the fan will not turn off until after the

mother board is off.

Internal Battery Operation

When turned on manually, the DECtalk can operate for about 5 hours using the internal batteries. In the automatic mode, the DECtalk can operate for 1 to 5 days without being recharged, depending on how much is spoken. It takes ten hours for the unit to be fully recharged. While being recharged, the DECtalk can still operate using the external 19 VAC adaptor, or an external 24 VDC power source.

Electronic Hardware

The heart of the power board design is the switchable 25 watt DC/DC converter (RIFA Model PKA 2231). It supplies the necessary +5, +12, and -12 volts for the operation of the DECtalk mother board. A full wave bridge network allows the use of a 24 DC or a 19 VAC source to power the converter. The data line of the RS232 port, and the FIFO ready line of the speech output circuitry on the mother board, are used to enable the power-up circuitry. An RC timing circuit is used to reset the mother board after power up and a digital counter is used to perform the power down time out functions.

Packaging

The finished portable DECtalk unit weighs 22 lbs. It is 15.75 inches long, 12 inches wide, and 3.5 inches high. The casing is made of aluminum. The portable DECtalk is designed to be mounted onto the back of any standard Everest & Jennings manual or electric wheelchair using the standard E & J electric wheelchair controller brackets. The circuit board is fan cooled, and is shielded against emitting radio frequencies. The internal electronics are protected against damage from rain when mounted on a wheelchair. The switches to select the operational mode and the internal or external power source are mounted on the control panel. The control panel also contains a volume control knob, an external speaker jack, fuses for the power board and the internal batteries, connectors for the charger and external power source, and an RS 232 connector.

DISCUSSION

Initialization

Since the DECtalk powers up each time before speaking a phrase in the automatic mode, it will always be in the default voice of Perfect Paul, the standard male voice. If the user wants to use another voice definition, the input string must always have an initialization string which selects or defines the desired voice. This is also true with other variable parameters which are not retained after power down, such as speech rate.

Serial Communications

Special attention needs to be made regarding the RS 232 serial communication from the host computer when in the automatic mode. The host computer must be able to send a character via the RS 232 port even though the DECtalk's RS 232 port is off. Some computers, such as the HX-20, have difficulty doing this. Also, the first character sent must be chosen so that it will not affect the spoken text if the DECtalk is already on. A space or the NULL character can be used. The host must then wait a minimum of 250 ms before sending the initialization string and text that is to be spoken.

Weight

The power requirements of the mother board are quite high, so large batteries are required to guarantee long operation as well as long life of the batteries. The batteries alone weigh 10 pounds. To support this weight, and to protect the circuitry from damage that could result from dropping the unit, the packaging was made from aluminum and weighs 6 pounds. The rest of the unit accounted for another 6 pounds, so the total weight of the system is 22 pounds.

Size

The limitations on how small the unit could be made were determined by the size of the mother board and of the batteries. The mother board is 10.5" X 15," and the batteries are 2.5" X 3.75" X 5.9" each, so the final size of 3.5" X 12" X 15.75" is about as small as possible (and is actually smaller than the orginal package from DEC).

Cost

The cost for a custom modification to a single standard DECtalk is approximately $2700. This modification includes $250 for the custom designed power supply, $2200 for packaging, and $250 battery, charger, and AC adapter.

CONCLUSIONS

The first unit has been placed with a non-vocal young woman who is using it daily at school on her E&J manual wheelchair. She uses a small external speaker in order to have the voice projected forward from the chair rather than sounding like it comes from the actual unit behind the wheelchair. She uses an Epson HX-20, a small portable lap computer, to input sentences to the DECtalk. She uses the predefined child's voice. She has been

very pleased with the quality of speech and its portability. So far, the DECtalk has lasted an average of 7 days on a single charge when in the automatic mode.

ACKNOWLEDGMENTS

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REFERENCES

"DECtalk DTC01 Owner's Manual" and
"DECtalk DTC01 Programmer's Manual"
By Digital Equipment Corporation
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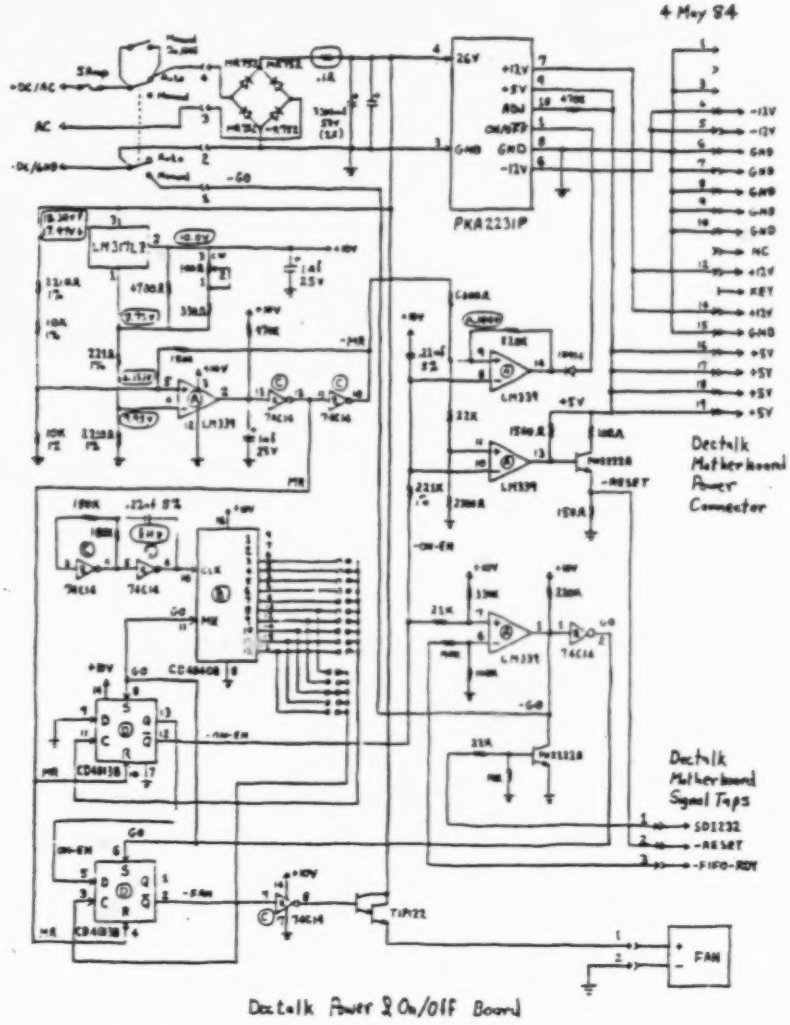

Dectalk Power & On/Off Board

TRACE AUTHORED PAPERS FROM THE NINTH ANNUAL CONFERENCE ON REHABILITATION TECHNOLOGY - 1986

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The Design and Testing of a Tutorial Manual That Allowed Users To Learn a Multifunction Aid System Without Expert Support

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Abstract: To see if a complex aid system could be learned from a manual without direct support from experts, a special tutorial manual was designed for a multifunction, computer-based, communication aid system called the Trine System. During the first two weeks of the Trine System's beta test, 13 users with their parents, therapists, and teachers were asked to learn the Trine System with the guidebook without contact with people who knew the system. After two weeks, six of the users were asked to demonstrate what they had learned. Five of the six users, as well as the father of the sixth user, had mastered the basics of the system.

In addition, five of the users and ten parents, teachers, and therapists were asked,"How likely is it that a user could learn the Trine System by using it with the guidebook without personal help from the supplier?" Eleven of these people rated this as "Very Likely" and the other four rated it as "Likely". No one rated it as "Unlikely" or "Very Unlikely".

The primary goal of the guidebook design was to allow people with normal intelligence who had no computer or complex aid experience to learn the Trine System without expert help from a printed document as physically accessible as possible to the disabled user. Secondarily, the guidebook was designed for small manufacturers to easily produce, maintain, and update in very small printing runs. To accomplish these goals, the Trine guidebook design makes use of structured documentation techniques, positive multimode presentations, and desktop publishing. As a result, the design includes many features not often found in aid system manuals. This study suggests that emulating these features may help users get the most from their aid systems and reduce the cost to manufacturers and dealers of personal support.

Question: Can Better Manuals Allow Users to Learn Aid Systems Without Expert Help? Aid systems are often underutilized because users are unable to learn from the documentation provided and are unable to get the expert support they need locally. Many users can't get expert help locally because they are in less populated areas and/or they are dealing with a manufacturer who has no local aid system integrator. In this case, many manufacturers are forced to provide aid systems via the mail and support them directly. For manufacturers who must use their technical experts to support systems directly, this can be doubly bad. It not only adds to the cost of the systems, but by tying up their designers, it also slows down the development of improved systems.

It is often suggested that if manufacturers would spend more effort developing quality tutorial manuals, they could mitigate these support problems. The better the manual, the less direct support they have to do. In the best case scenario, the tutorial manual would be good enough to allow users along with their local support group (parents, teachers, therapists, etc.) to master their aid systems without any additional help from experts on that particular aid system.

Testing: The Trace Center Tested the Idea In Developing the Trine System. The Trace Center decided to test the idea that a good tutorial manual would allow users to learn a complex aid system without help from anyone already an expert on that particular system. As a result, two major activities were added to the development of a portable computer based communication aid system called the Trine System. First, great emphasis was put on the design and production of a tutorial manual that we call *A Journeyer's Guide to the Trine System* (hereafter referred to as the Trine guidebook). Second, part of the beta test of the Trine System was designed to see whether or not people could learn to use the communication aid system from the guidebook and their own experimentation, without help from people familiar with the system.

What Is the Trine System Like? In order to understand how effective the tutorial guidebook it is necessary to understand what the Trine System is like and what there is to learn. The Trine System is a multifunction aid system whose primary components are a software program, an Epson HX-20 portable computer, and an optional speech synthesizer. It has three main functions: providing a portable writing system; providing a portable speech output system; and providing access to a standard computer through a standard keyboard emulating interface.

The Trine System is designed to be easy to use by beginners while providing flexibility for more advanced users. It uses menus and dedicated keys for most functions. However, it's flexiblity means there is a lot to learn if a person wants to master everything. It has 143 different menus and there are about 33 functions on dedicated keys including 22 editing functions. Four of the keys cycle sequentially through three different states. The Trine System offers six different writing workspaces, a conversation workspace, and keyboard emulating interface workspace. It can use a built-in or external printer,and a built-in or external speech synthesizer. It has a two mode abbreviation expansion system that can store about 400 twelve character user programmable expansions. A built in cassette drive stores abbreviations as well as up to 18 pages of writing organized into three different volumes. Almost all program parameters are user setable. To cover all these features the guidebook is itself 327 pages with 123 major topic articles.

Who Were the Test Users? As part of the Trine System evaluation a beta test was carried out with six users from Wisconsin (Level 1 users) and seven users from other areas (Level 2) users. Figure 1 profiles the test users, showing their sex, age, grade level, and whether or not they walk or use a speech synthesizer. Level 1 users ranged in age from 11 to 40 and in grade level from third to the second year of college. Users in Level 2 ranged in age from 10 to 47 and in grade level from third through college. Each group had one female. Two of the level 1 children walk, and one Level 1 person along with three Level 2 persons use a speech synthesizer with their Trine System.

User	Sex (Female / M)	Age	Grade	Ambulatory (Yes / N)	Uses Speech Synthesizer (Yes / N)
			Level 1		
#1	M	11	3	N	Yes
#2	M	40	4	N	N
#3	M	11	5	Yes	N
#4	Female	11	5	Yes	N
#5	M	15	4	N	N
#6	M	30	14	N	N
			Level 2		
#7	M	47	16+	N	N
#8	M	15	9	N	N
#9	M	10	3	N	Yes
#10	M	27	12	N	Yes
#11	Female	17	11	N	Yes
#12	M	17	3	N	N
#13	M	13	8	N	N

Figure 1: Profile of Test Users

An important point to keep in mind about the beta test users is that in order to participate they had to already have an Epson HX-20 computer because the project could not afford that many computers. This means that they all had some experience with the Epson computer before they got the Trine System. Thus, they were not naive users. However, we feel that their experience still relates to other beginning users because the Trine System is very different from software that they used previously. In fact, they may have had some extra problems due to expectations about how they thought it should work from their other experience .

The Test Users Had Only the Trine Guidebook For Support During the First Two Weeks: The overall beta test was designed to evaluate the Trine System as a communication aid system and the results are given in the Trine beta test report[1]. One procedure of the beta test was designed to see if the six Level 1 users could learn the basics of the Trine System without help from experts. These people were

given the Trine System and the guidebook and asked to learn it without help from the Trace Center. If they called with a problem they were preferred to the guidebook in general, not to any particular section.

Results: Five of Six Users Mastered the Basics In Two Weeks. After two weeks the Level 1 users and their associated support persons came to the Trace Center for evaluation. Susan Fishman, beta test coordinator for the project, then tested them to see whether they had mastered the basics of Trine System use. The following is her conclusion in the beta test report:

After two weeks of using the Trine System without any direct training by the Trace Center subjects in Level 1 were asked to demonstrate basic functions of the aid. Five out of six of the subjects were able to get into different workspaces, delete characters, lines, and pages, move the cursor in all directions, insert words and print on the built-in printer. In the case of the one subject who was not able to perform all these functions the father was able to demonstrate them. The skill demonstrated by either the subjects themselves or their primary trainers suggest that it is possible to learn the basic operation of the Trine System using the training manual in conjunction with hands on exploration without external support or training. All subjects in Levels 1 and 2 agreed that they were provided with sufficient information to learn the basic functions of the Trine System and did not require any direct training. In addition, three subjects had incorporated the system into their classes or daily environment within two weeks.[1]

What The Test Users, Their Parents, and Clinicians Thought About Learning From the Trine Guidebook: Between the two and four week point Level 1 and Level 2 users were interviewed on their thoughts about the guidebook. In three cases parents and clinicians were interviewed instead of the users because they were learning the system themselves and then teaching the users who were at the third and fourth grade level. In addition, two parents and five clinicians who also learned the Trine System were interviewed.

The five users, five parents, and five clinicians interviewed about the guidebook were asked, "How likely is it that a user could learn the Trine System from using it with the guidebook (with help from family, friends, and inexperienced clinicians) without personal help from the the supplier." They were given four choices: Very Unlikely; Unlikely; Likely; or Very Likely. The results are shown in Figure 2. Eleven of these people rated this as "Very Likely" and the other four rated it as "Likely". No one rated it as "Unlikely" or "Very Unlikely".

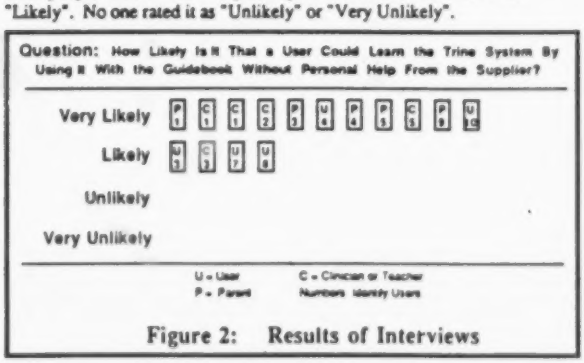
Question: How Likely Is It That a User Could Learn the Trine System By Using It With the Guidebook Without Personal Help From the Supplier?
Very Likely
Likely
Unlikely
Very Unlikely
U = User
P = Parent
C = Clinician or Teacher
Numbers Identify Users

Figure 2: Results of Interviews

Thus, users, parents, and clinicians strongly endorsed the idea that the Trine System could be learned from a tutorial manual without the need for training by experts in the system. Considered with the results of the beta test finding discussed above, this indicates it is likely that manuals similar to *A Journeyer's Guide to the Trine System* can reduce the need for personal training and other direct support for other complex aid systems.

Design: The Trine Guidebook Design Makes Use of Structured Documentation Techniques, Positive Multimode Presentations, and Desktop Publishing. The primary goal of the guidebook design was to create a printed document as physically accessible as possible that would allow a disabled user with normal intelligence, a sixth grade reading level, and no computer or multifunction aid experience to learn the Trine System without expert help. Secondarily, the guidebook was designed for small manufactures to easily produce, maintain, and update in printing runs of as few as 50 copies. To accomplish this three major approaches were incorporated into the design.

The first major approach used is called structured documentation. The author learned the structured documentation approach from a 2 day workshop, Structured Documentation, presented by The American Institute for Professional Education (Carnegie Bldg., 100 Kings Rd., Madison, NJ 07940, (201)377-7400). According to the presenter, Lynn Harris, structured documentation evolved from the intense documentation and training requirements for computer software in companies like IBM, Wang, and Digital Equipment Co. Its overriding goal is to make is possible to design, produce, and maintain effective documentation in the most cost effective and time effective way. Structured documentation can be done successfully by any size company. The three main features of structured documentation are that it is: 1) modular, 2) structured in a top-down fashion, and 3) written using clear communication techniques

The second major approach was to design, write, typeset, print and assemble the guidebook in-house using the Apple Macintosh computer system. This has since come to be called desktop publishing. Because most small aid system companies print 100 or fewer manuals at a time, the cost to produce quality tutorial manuals using traditional publishers and bookmaking techniques is prohibitive. Desktop publishing offers the possibility to aid system companies of making quality manuals. The overall design and layout of the guidebook was strongly determined by technical limitations of the Macintosh. It turned out that these limitations severely increased the effort required to create the guidebook. Happily, most of these limitations have been removed in the latest equipment.

The third major approach was to incorporate new ideas about different cognitive learning styles by using a positive multimode presentation of key information. To communicate effectively to a wide variety of people, the guidebook presents the same information in a variety of ways. Information was always presented positively in the logical sense. Negations were actively eliminated. The five main types of presentation were: 1) a summary, 2) straight text, 3) a follow along example, 4) a realistic illustration of the actual device, and 5) a tabular instruction list. This redundancy is relatively cheap when implemented with desk top publishing equipment. It was found from interviews with the learners that even in our small sample of 15 that the group was almost evenly split for their primary learning among all five types of presentation. It is felt that the positive style and redundancy in the guidebook contributed greatly to its success. This is like the organization and redundancy in a Space Shuttle. It's a necessary redundancy if it is to work.

The Trine Guidebook Includes Many Features Not Often Found In Aid System Manuals: The structured documentation techniques, positive multimode presentations, and desktop publishing approach led to a tutorial manual design with features not often found in aid system manuals. Figure 3 shows a typical topic layout. In this paper features of the guidebook design can only be briefly listed:

Overall Features of *A Journeyer's Guide to the Trine System*:

1) Modularity
2) A Multimode Presentation
3) Textual and Visual Redundancy
4) Topics Defined by the Actual Tasks a User Wants To Do
5) Each Topic Is Self Contained
6) Reader Encouraged To Only Look At Relevant Topics
7) Directly Addresses Reader
8) Positive Statements Only
9) Written For a 6th Grade Reading Level
10) Descriptive and Mnemonic Titles
11) Descriptive Headlines
12) Summaries In Each Topic
13) Examples For Each Task
14) Descriptive and Mnemonic Page Numbers

Physical Features:

1) Made With Half Sheet Size Three Ring Binders
2) Binders Have Slip In Covers
3) 6 1/4" x 8 1/2" Pages
4) Large 5/16" Binder Holes and Sheet Lifters
5) Pages Printed On Colored Copypaper Stock
6) Tabs Printed On Colored 110# Cover Stock With Mylar Reinforcing

Organization Features:

1) Six Distinct Color Coded Parts: 1 Opening, 2 Using the Trine System, 3 Troubleshooting, 4 User Tips, 5 Connecting & Adjusting, 6 Reference & Index
2) An Instant Demonstration On the Very First Page
3) Tabs At Every Section
4) Complete Table of Contents At Its Own Tab
5) The Contents of the Section Listed At Its Beginning
6) The Main Points of the Section At Its Beginning
7) The Contents of Adjacent Sections Listed At the Beginning of Each Section
8) An Expandable User Tips Section For Notes With Helpful Tips Written By Actual Users
9) A Distinctive Red Troubleshooting Section At Its Own Tab
10) A Complete Glossary At Its Own Tab
11) A Complete Index At Its Own Tab

Layout Features:

1) A Basic Layout Repeated For Each Topic
2) Each Topic Has Text Page and a Facing Visual Exhibit Page
3) Headlines 18 pt. Bold Times-Roman Type (72 pt. to an inch)
4) Ruler Lines To Set Off 12 pt. Helvetica Summaries
5) Text 10 pt Helvetica With Bolded Keynames and Menu Items
6) Eye Catching Symbols In the Left Margin Marking Special Paragraphs
7) Exhibit Page Has 14 pt. Caption
8) Realistic Screen Illustrations
9) Realistic Keyboard Illustrations
10) Tabular Instruction Lists

Production Features

1) Designed In-House using the Apple Macintosh and Macpaint
2) Typeset In-House Using Apple Macintosh. The edition tested was done on 80 dpi Apple Imagewriter and the second edition (Figure 3) was done on 300 dpi Apple LaserWriter.
3) Printed Via Photocopier (Except Tabs Which Were Offset Printed)

Conclusion: This study suggests that tutorial manuals like *A Journeyer's Guide to the Trine System* with the features listed above can allow users of complex computer based aid systems to learn these systems without expert help. This type of manual might allow more users to get the most from their aid systems and might reduce the cost to manufacturers and dealers of personal support.

1. Beta Test Report for DOE Grant 300-83-0267, Technology Compensatory Activities, July 1985, Trace Research and Development Center, University of Wisconsin-Madison.

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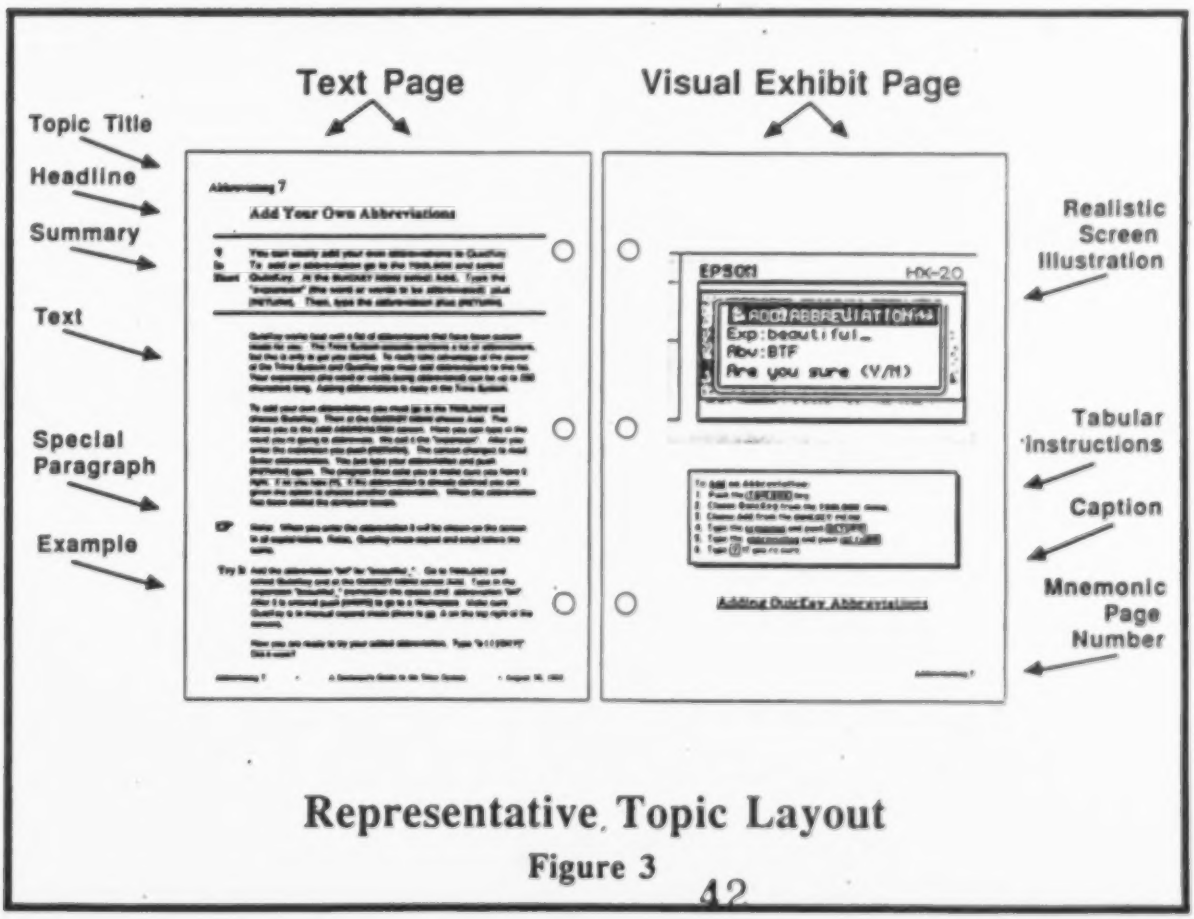

Representative Topic Layout

Figure 3

BEST COPY AVAILABLE

One Finger Operation of the IBM Family of Personal Computers

Charles C. Lee
Gregg C. Vanderheiden
Arthur Rasmussen

ABSTRACT

Software programs to allow one finger operation of the IBM family of Personal Computers have been written by the Trace Center at the Waisman Center, University of Wisconsin. The programs remain resident in the computer once invoked. A different program is required for the IBM PC/XT, the IBM PCjr, and the IBM AT since each computer handles the keyboard a little differently. The programs provide many options to allow the user to configure the program to meet their specific needs and situation. Options include: tri-state shift keys, audible feedback on the states of the shift keys, manual turning on and off of the program, audible feedback when the program is manual turned on or off, user selectable delay time on the automatic repeat of the keys from 0.5 seconds to 60 seconds in 0.1 second intervals, automatic turning off of the program if a shift key and any other key is held down at the same time, and automatic turning off of the program if there is no activity at the keyboard for a user selectable time from 1 to 60 minutes in 1 minute intervals. All of the above options are set by software switches. Also, there are options to have the program be on at start-up, to show the status of all the options on the screen at start-up, and to un-install the program.

INTRODUCTION

Many handicapped individuals can only use a keyboard with one finger, a mouth stick, or a headstick. This introduces three problems. The first is the problem of holding down two keys at the same time. This problem exists when trying to hold down a shift key (Left Shift, Right Shift, Ctrl, and Alt, and the Fn for the PCjr), and another key.

The second problem is the automatic repeat of a key. Many handicapped individuals, especially those with cerebral palsy, are slower in their hand or finger movements when typing on a keyboard. The IBM computers automatically repeat the key if it is held down for more than 1/2 a second (delay time) and repeats the key at 10 characters per second (typematic rate). Yet it takes some individuals 2 second before being able to release the key which means that they would get as many as 10 extraneous characters.

There are programs which currently deal with either one of the problems, but not with both. These programs also do not deal with the third problem of what to do when handicapped and non-handicapped individuals use the same computer, since the tri-state shift keys and the increased delay time on the automatic repeat is not generally desirable for the non-handicapped individual. This poses a difficult problem when the non-handicapped person is not able to exit the current application program or reboot the computer.

IBM KEYBOARD OPERATION

The keyboards of the IBM family of personal computers operate in a similar but not identical fashion. Each key has a code which identifies it, called a scan code. When a key is depressed, the keyboard sends to the computer a down scan code of the key which was depressed. When the key is released, the keyboard sends to the computer an up scan code of the key released. If the key is held down for the set delay time, the keyboard sends down scan codes to the computer at the typematic rate. If a new key is pressed down when a old key is repeating, the old key's scan code is no longer sent to the computer. Instead, the new-key's scan code is sent to the computer. It is up to the computer to determine how to treat the information received from the keyboard. Every time the computer gets a scan code from the keyboard, it interrupts whatever it is doing, translates the scan code into a key and performs the appropriate action. The program that does this is called the keyboard interrupt routine. The interrupt routine keeps track of the state of the shift keys in a set memory location. The address to the interrupt routine is placed in an interrupt vector.

DESIGN GOALS

1. To allow one finger use of the shift keys.

2. To allow a selectable automatic repeat key delay time and to set the typematic rate accordingly.

3. To provide manual means to turn on and off the program for the user.

4. To provide an optional feature which would detect when a non-handicapped user was using the computer and turn off the first and second features listed above.

METHODOLOGY

The goals were accomplished by writing a new keyboard interrupt routine that would be executed instead of the original keyboard interrupt routine. The new routine then makes the keyboard behave differently by handling the scan codes differently. It still uses the original keyboard interrupt routine to translate the keys and to perform certain action (e.g., rebooting with CTRL-ALT-DEL). When the program is loaded, it changes the interrupt vector for the keyboard so that the new keyboard interrupt routine is executed instead of the original keyboard interrupt routine. It then installs the new keyboard interrupt routine into memory, where it remains resident, even when other programs are running. If the program is loaded a second time, it determines whether the new keyboard interrupt routine is resident; if so, it change only the options of the interrupt routine and does not install another copy of the routine in memory.

DESCRIPTION

Tri-State Shift

The program supports the option of a tri-state shift on the Right-Shift, Left-Shift, Ctrl and Alt keys (also the Fn key on the PCjr). Depressing and releasing a shift key once makes it active for the next non-shift key. Depressing and releasing a shift key a second time (before any non-shift key) locks the shift key in an activated state until unlocked. Depressing and releasing the shift key unlocks the key if it is in the locked state.

More than one shift key can be shifted or locked as long as all of the shifting or locking is done before depressing a non-shift key. Depressing a non-shift key changes all shift keys in the shifted state to a non-shifted state, but leaves those in the locked state alone.

Delayed Repeat

The delay repeat option allows the user to set the delay time for the automatic repeat. It can be set from 0.5 seconds to 60 seconds in 0.1 second intervals (on the AT it can be as low as 0.3 seconds). This will only be effective on the non-shift keys. The key will then automatically repeat at a rate of half the time of the delay. For example, if the delayed repeat time is set at 2 seconds, the key must be held down for 2 seconds before it will be automatically repeated. It will then repeat every second until the key is released or another key is depressed. The automatic repeat can be effectively disabled by setting the delayed repeat time to 60 seconds.

Manual On/Off

The program can always be manually turned on and off by the user. To turn on the program, the Left-Shift key must be depressed and released four times in a row. To turn off the program, the Right-Shift key must be depressed and released four times in a row. This allows the knowledgeable handicapped or non-handicapped user to turn the program on or off.

Automatic Turning Off

This option is very important if a non-handicapped and a handicapped individual use the same computer. It allows the one finger program to turn itself off so that it does not prohibit the non-handicapped user from effectively using the keyboard.

There are two ways the program can automatically turn off. Both are options. The first option is to have the program watch for a shift key and then any other key depressed simultaneously (something a one finger typist does not do). The program then turns itself off and the keyboard performs as it normally would.

The second way that it automatically turns itself off is when there is no activity at the keyboard for a set period of time (time out). The time out can be user selectable from 1 to 60 minutes in 1 minute intervals. This is useful in cases where the handicapped user leaves (without turning the routine off) and a non-handicapped user comes several minutes later to use the computer. The program will already have been turned off by the time the non-handicapped user begins.

Neither of these methods require any knowledge of the non-handicapped user about the special functioning of the one finger program.

Note: Even if the two key turn off option is not selected, the states of the shift key registers are set to their actual states if a shift key and another key are depressed at the same time. In this way, the keyboard will always act like a normal keyboard when two or more keys are held down.

Feedback

Feedback to the user is very important in any application. This is especially true when a single action, like pressing a key, can have more than one result. Audible feedback is provided via the speaker to indicate the new shift state when a shift key is depressed. A low and then a high beep is used to indicate the shift key is now in the shift state. A single high beep is used to indicate the shift key is in the locked state. A single low beep is used to indicate the shift key has been unlocked.

There is also audible feedback when the program is manually turned off or on. A low to high rising tone indicates that the program is now turned on, and a hi to low falling tone indicates that the program is now turned off.

The current status of all the options can be displayed when the program is run to give feedback to the user on the current set-up.

Uninstalling the Interrupt Routine

The keyboard interrupt routine can be uninstalled by selecting the uninstall option when running the program. The new keyboard interrupt routine will then no longer intercept the keyboard scan codes from the original keyboard interrupt routine. However, the memory space cannot be regained for use without rebooting.

Applications

This program is excellent for individuals who can type with only one finger or the equivalent (headsticks, mouthsticks, etc.). It is also useful for non-handicapped individuals, since there are many times that a non-handicapped individual has use of only one hand when at a computer (e.g., the other hand is holding down pages to a book or doing something else). The program is useful to those who are slow at releasing a key once it is depressed whether they need the shift feature or not.

REFERENCES

IBM Technical Reference PC
IBM Technical Reference XT
IBM Technical Reference PCjr
IBM Technical Reference AT

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Application of Multiple Wordstudy Analysis in the Development of Vocabularies for Augmentative Communication Systems

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ABSTRACT

While many studies of word frequency use have been conducted with normal individuals, it is difficult to determine the extent to which this reflects the speech of a given client or situation. Even the top fifty most frequently used words may differ by more than 50% between different word frequency studies. Although some words are consistently high frequency across all settings, frequent variation in vocabulary production is reported between population samples discriminated by age, mode of output, task, setting, sampling method, and units of analysis. A wordset for an augmentative communication system is ideally tailored to a client's age and educational level but applicable across settings and communication modes; frequency information for a wordset should then be based on an appropriate sample(s) and augmented by information on vocabulary variation across relevant settings/modes. This paper outlines considerations and available resources for vocabulary selections utilizing frequency data, based on an overview of a bibliography collected at the Trace Center, Madison, WI, of over 350 studies related to vocabulary frequency in normal individuals.

The most frequently quoted reference in psychological or educational research for relative frequency of vocabulary use is still Thorndike (1944). However, Thorndike and many other large scale studies (Kucera & Francis, 1967; Carroll et. al., 1971; Zettersten, 1978) are derived from analysis of printed texts rather than productive written or spoken interaction. These types of text analyses are appropriate for many educational tasks, such as estimating readability, but are not intended to be estimates of word frequency in conversation or written interaction. Studies of spoken or written production (such as Howes, 1966; Wepman & Hass, 1969; Schonell et al., 1956; Fitzgerald, 1934) more closely relate to output of communication systems, but tend to analyze a single setting and a much smaller dataset and may be limited in their application across settings. Any single study is limited by size and representativeness of sample, and even the Beukelman et. al. (1984) sample of output by communication aid users has limited utility for recommending wordsets for augmentative systems, because of the high variability between individuals, settings, and other linguistic factors.

A demonstration of the degree of potential variability between wordsets is provided in Table 1. For this study, the Thorndike list was used as a base. Ratios indicate the percentage of the top 50 words of 13 wordset studies as compared to the top 50 words of the Thorndike study. The 50-word samples from the 13 studies differed by 14-54% from the wordset derived from Thorndike. More importantly, the words which contribute to the variation differ according to the population sample (child, college

TABLE 1

% SIMILARITY IN TOP 50 WORDS
BETWEEN THORNDIKE AND OTHER WORD FREQUENCY STUDIES

Frequency Study	Sample Characteristics	% Agreement
Kucera & Francis (1967)	A/ta/1,000,000 words	86%
Dewey (1923)	A/ta/100,000 words	84%
Black & Aursherman (1955)	A/s/college student speeches	78%
Horn (1926)	A/w/personal and business leters	76%
Rinsland (1945)	C/w/children's school themes	72%
Beukelman & Yorkston (1984)	A/s,w/augmentative communication aid users	68%
Berger (1976)	A/s/college student conversations	64%
Jones & Wepman (1966)	A/s/picture descriptions	64%
Wepman & Hass (1969)	C/s/picture descriptions	60%
French, Carter & Koenig (1930)	A/s/telephone conversations	60%
Fitzgerald (1934)	C/w/4th-6th grade personal letters	58%
Edwards (1964)	C/w/free writing	48%
Cameron (1970)	A/s/college student conversations	46%

A = adult
C = child
s = spoken production
w = written production
ta = text analysis

students, adults), mode (speech, writing, text), setting (school, home, office, public places), task (free writing/speech, conversation, formal themes/speeches), and other sample characteristics. For example, some of the words unique to the top 50 of different populations include: contractions used in slang, e.g. "I'll, You're," and profanity (college student speech), words like "play, gonna, boy, put, house" (children's speech), and words like "please, seem, would, because" (adult writing). Even a combined wordset derived from word frequency studies across all settings has limited application for communication aid selection: it would both exclude high frequency vocabulary unique to a given population or setting, and include vocabulary unrepresentative of client or sample characteristics

The following are a series of observations and resources for normative data to assist adaptation of vocabulary sets, based on review of over 350 sources related to vocabulary frequency collected at the Trace Center. (Complete copies of the bibliography are available from the Trace Reprint Service).

The top 10-20 words, such as "you", "a", "and", "the", and "in", tend to be consistently frequent across wordsets from all communicative settings. Most words within the top 100 are also frequent across different wordlists, but include unusually frequent words characteristic of a given sample or setting (such as profanity, or words about play). Beyond 100 words, it becomes increasingly difficult to predict relative frequency of any words across wordsets, except within a setting utilizing limited vocabulary (such as writing letters about farming equipment). Because of the high variability of human linguistic output, word frequency lists are best used only as a sample vocabulary rather than sole determiner of a communication aid wordset.

For some clients, supplemental wordsets for limited professional or educational purposes may be appropriate. Normative data is available listing the most frequently used words for specific professional tasks such as technical writing, business letters, classroom speeches, and other vocational purposes (e.g. Johansson, 1978; Hartsough & Laffal, 1970; Cole, 1940). Also, some frequency or core vocabulary studies provide suggestions for vocabulary related to such disabilities as CP, MR, deafness, and cultural disadvantage (e.g. Irwin, 1966; Mein, 1961; Walter, 1978; Sherk, 1973).

If part-word units are utilized as spelling aids, the applicability of frequency ranking of words changes, even if only 50 words are coded in a device. For example, introducing "the" as a spelling aid as well as a word alters the usefulness of including the following high frequency words: the, then, them, they, their, there, and these. Data available on frequent letter/phoneme sequences can help predict which phoneme sequences occur most frequently, and which of those represent linguistically relevant units (see Carterette & Jones, 1974; Hanna, et. al. 1966; Roberts, 1965; Solso, 1979).

Most top 50 lists also include items with closely related content, such as have/had/has. Wordlists such as Basic English propose a representative set of words to fulfill a range of related meanings in order to reduce such perceived redundancy (Ogden, 1932; West, 1953). While Basic English is controversial as sole medium of communication, principles may guide training to minimize redundancy of wordsets and number of words used to express ideas.

Determining vocabulary for communication aids must balance between flexibility and ease of use. Ideally, all possible sentences or units of sentences could be easily coded and retrieved, but the cognitive load of remembering codes would eventually interfere with performance. This is true however the vocabulary is coded. Various studies for measuring cognitive load of a language sample may be useful for determining size and arrangement of wordset. Pertinent information includes readability (Chall, 1958), syntactic units (Corson, 1982), encoding strategies (Paap & Ogden, 1981), and other processing demands (Schwartz, 1976; Schneider & Shiffrin, 1977).

Communication devices must often serve as both speaking and writing aids for clients. This makes vocabulary selection more difficult, because the processes and vocabulary uses are different between these two communication modes: e.g. speech is typically faster and more often redundant than written communication. Studies such as those by Chapanis et. al.(1977), Weeks (1976), and Earl & Goff (1965) describe differences in vocabulary and communication strategies between speech and writing, as well as analyzing the effects that different communication devices have on language content and use.

For augmentative system users, relative speed is reflected in the number of keystrokes or motions necessary to convey a message. The longer and more frequent a word, the greater the keystroke savings if that word is represented by a reduced code. Current frequency studies reflect only frequency rankings, and need to be reorganized by length/frequency information to facilitate calculation of keystroke efficiency.

Greater keystroke savings may also be accomplished by coding the most frequent phrases or word combinations as well as words. Hart, Walker & Gray (1977) provide normative data on the most frequent 2- and 3-word phrases used by children, which include: "I'm going", "I'm not", "I don't know", and "I want to". Even if some phrases or sentences provide fewer objective keystroke savings than words, it may be appropriate to include them on communication aids. Particularly in conversation, the most important words/phrases may not be what is said most often, but what is needed to say most quickly.

It is certainly possible to derive a list of 50, 100, or 200 frequent/useful words without utilizing any frequency or related information. However, individuals are reported to be poor at identifying or estimating frequency of words, with a tendency to note unique utterances or omit functor words. In deriving a communication aid wordset, clinicians must try to balance normative data on word frequency with clinical impressions and limited samples of linguistic output from a client. One of the functions of research is to provide maximum information about the application of word frequency information across different settings, to minimize clinician effort to fit the communication aid to the person, situation, or task.

In summary:

- We have more resources available for wordset selection than the straight word frequency studies we have been using; other available information includes normative data on technical vocabularies, vocabularies for special populations, differences in language and strategies between communicative modes, frequencies of letter/phoneme sequences or conversational phrases, semantic reduction, or cognitive loading of different coding strategies.

- Single vocabulary frequency studies alone are limited in application to the sample they study, and combined wordlists

across different settings often obscure important differences between age groups, settings, tasks, or sampling techniques. Instead, comparative information derived from frequency and related studies can provide data on group differences to justify and apply clinical impressions of individual differences in vocabulary use.

Selected References

Beukelman, D.R., Yorkston, K.M., Poblete, M., Naranjo, C. (1984) Frequency of word occurrence in communication samples produced by adult communication aid users. Journal of Speech and Hearing Disorders, 49, 360-367.

Cameron, P. (1970) The words college students use and what they talk about. J. Comm. Dis., 3, 36-46.

Carroll, J., Davies, P. & Richman, B. (1971) American Heritage Word Frequency Book. Boston: Houghton-Mifflin Company.

Carterette, E.C. & Jones, M.H. (1974) Informal Speech. Berkeley: University of California Press.

Chapanis, A., Parrish, R., Ochsman, R. & Weeks, G. (1977) Studies in interactive communication: II. The effects of four communication modes on the linguistic performance of teams during cooperative problem solving. Human Factors, 19, 101-126.

Cole, L. (1940) The Teacher's Handbook of Technical Vocabulary. Bloomington, Ill.: Public School Publishing Company.

Corson, D.J. (1982) The Graeco-Latin (G-L) instrument: A new measure of semantic complexity in oral and written English. Language and Speech, 25, 1-10.

Dewey, G. (1923) Relative Frequency of English Speech Sounds. Cambridge: Harvard University Press.

Fitzgerald, J. (1934) The vocabulary of children's letters written in life outside the school. Elementary School Journal, 38, 358-370.

Hartsough, R. & Laffal, J. (1970) Content analysis of scientific writings. Journal of General Psychology, 83, 193-206.

Irwin, O. (1966) A comparison of the vocabulary of use and of understanding of cerebral palsied children. Cerebral Palsy Journal, 27(3), 7-11.

Jones, L. & Wepman, J. (1966) A Spoken Word Count. Chicago: Language Research Associates.

Kucera, J. & Francis, W.N. (1967) Computational Analysis of Present-Day American English. Providence: Brown University Press.

Mein, R. (1961) A study of the oral vocabularies of severely subnormal patients. Journal of Mental Deficiency Research, 5, 52-59.

Roberts, A. Hood (1965) A Statistical Linguistic Analysis of American English. The Hague: Mouton & Company.

Schneider, W. & Shiffrin, R. (1977) Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review, 84, 1, 1-3+.

Schwartz, S.P. (1976) Capacity limitations in human information processing. Memory and Cognition, 4(6), 763-768.

Sherk, J.K. (1973) A Word-Count of Spoken English of Culturally Disadvantaged Preschool and Elementary Pupils. Kansas City: University of Missouri.

Solso, R.L. (1979) Positional frequency and versatility of letters for six-, seven-, and eight-letter English words. Behavior Research Methods and Instrumentation, 11, 355-358.

Thorndike, E. & Lorge, I. (1944) The Teacher's Word Book of 30,000 Words. New York: Teacher's College, Columbia University.

Weeks, G. & Chapanis, A. (1976) Cooperative versus conflictive problem solving in three telecommunication modes. Perceptual and Motor Skills, 42, 879-917.

Wepman, J. & Hass, W. (1969) A Spoken Word Count: Children Ages 5, 6, and 7. Chicago: Language Research Associates.

West, M. (1935) Definition vocabulary. University of Toronto Bulletins of the Department of Educational Research, 4, 1-105.

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